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## ABSTRACT

This is the first book in a sequence of four volumes written and designed for parents of students of science, particularly for those at the lower and upper elementary and junior high or intermediate level, senior high students, college students preparing to teach science, and all those individuals who are interested in science and the application of science in daily life. This volume consists of five chapters that contain 129 discrepant events (occurrences or happenings which go against what we usually think likely) dealing with the properties of matter in the immediate environment. Each of the chapters contains demonstrations that can be used to build lessons dealing with air, flowing air, weather, characteristics of matter, and chemicals. Instructions for each event include materials, procedure, questions, and an explanation. Emphasis is placed on the use of simple materials. An appendix contains data tables required by the events. A list of available science educational materials from Science Inquiry Enterprises is included and an index is provided. (LZ)

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# Turning Kids On To SCIENCE

IN THE HOME

ED 378 061

BOOK 1



## OUR ENVIRONMENT

Easy to follow recipes for doing 150 science activities in Air, Weather, Matter & Chemicals in our environment, with very simple materials found in and around the house.

**Dr. Tik Liem**

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*Turning Kids On To*

# SCIENCE

IN THE HOME



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Easy to follow recipes for doing 150 science activities in Air, Weather, Matter & Chemicals in our environment, with very simple materials found in and around the house.

**Dr. Tik L. Liem**

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Book 1 - OUR ENVIRONMENT"**

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TO THOSE PARENTS  
WHO WANT TO PUT MORE *Excitement*  
IN THEIR CHILDREN'S LIFE



 **CAUTION** 

- \* Only with adult supervision may children use this book!
  - \* Fire may only be used with adult supervision!  
All fire hazardous events are marked with this symbol: 
  - \* Chemicals and/or electricity may only be used under adult supervision!  
Never touch chemicals with your bare fingers: poisonous chemicals can even be absorbed through the skin!  
Hazardous events involving chemicals are all marked with: 
  - \* The use of chemicals always brings with it some hazards. It can be dangerous, but when handled properly it can be lots of fun!
  - \* When working with a flame or when a flame is involved in an event, always have a carbondioxide or Halon fire extinguisher at hand.
  - \* Always follow instructions - the "How to do it" - very carefully!
  - \* Never work all by yourself. Always have someone with you ready to turn the fire or electricity off, if something goes wrong.
- \* The author of "**Turning Kids On To Science In The Home**" is not responsible for any accidents resulting from irresponsible or incompetent use of the demonstrations and activities suggested in this book.
- \* Although some events are rather dangerous, but if the instructions are carefully followed, they can give you a lot of joyful moments!

*So, have lots of fun!*

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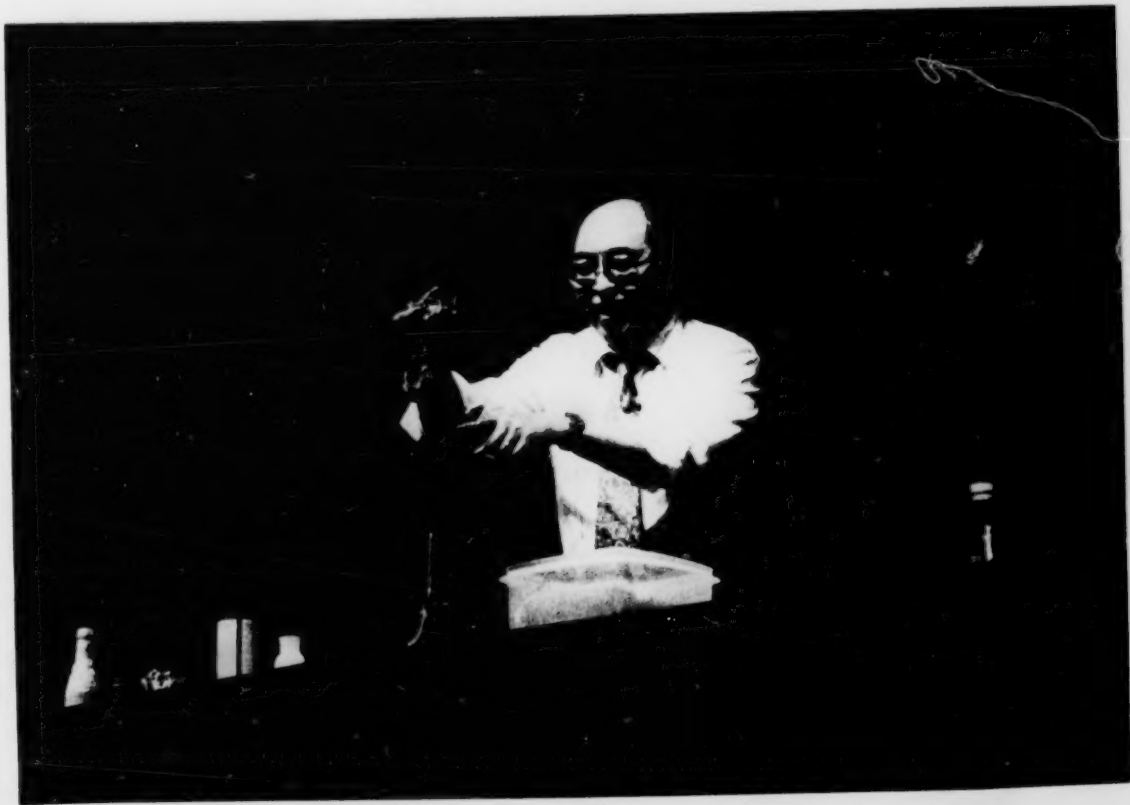
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Be a  
*Happy* and *Enthusiastic*



**Teacher to  
your children !**

# INTRODUCTION

**This book** is written and designed for parents of students of science, particularly for those at the lower and upper elementary, and junior high or intermediate level, for senior high students, for college students preparing to teach science, and for all those individuals who are interested in science and the application of science in our daily life.

**In this space age** where science plays a major role in determining whether a country or even a personal life will be able to advance or progress, I feel that the understanding of science concepts and science principles will strongly help towards this goal. Statistics and test results have shown that American youngsters can't perform the simplest technical functions. A recent report of a study done by the Educational Testing Service in Princeton, New Jersey mentioned that American nine-graders were compared with same age level children of five other countries and four Canadian provinces, and they came out on the bottom in mathematics and very near the bottom in science! This is very sad news, even worse is their prediction that in the year 2000 there will be a shortage of close to a quarter million engineers, physicists, chemists, and biologists in the USA.

**Where lies the problem?** What makes the USA so lagging behind other countries, like: Japan, Western European countries, and in recent years some of the Pacific Rim countries? This lagging is not only economically, but especially in academic achievements of students in the field of mathematics and science! Could it lie in the way math and science is being taught in our schools? Could it lie in the way math and science is being presented to our young children? These questions come up in my mind when too many children I talked to said, that they do not like math and science in their schools. Could the problem be that school teachers do not have enough background in mathematics and science? And because of this, that they are conveying the message to students that math and science are a chore and really not fun to study? Could it be that schools do not have enough materials for doing science? Could it be that at home, our young children are also not getting any encouragement from their parents to go in the fields of science and mathematics?

**I think** it is a combination of all those mentioned, especially I think that not enough **enthusiasm** in science is being shown in the home as well as in the schools. If teachers as well as parents of students can show more excitement and **enthusiasm in science**, and not be afraid to actually show their enjoyment in doing science in front of the children, there is no doubt in my mind that more of our younger people will find science exciting, and continue studying in the field of science!

**In the teaching** of a science concept, it is most essential for the teacher to arouse the students' curiosity. Unless the student wants to know what the teacher has to say, it is most likely that time and effort in trying to teach the student would have been completely wasted. The first task of a teacher is to attract the attention of the student. This goes for all levels of learning, whether it is primary grade or college. A student without interest is the desperation of any teacher. In fact, the main objective of formal education is the arousing of the students' interest, if nothing else. Once curiosity is aroused the student will learn much more on his/her own than the teacher can ever teach him/her. Learning only takes place if the student wants to learn!

**In this book** the description of each of the **exciting events** is organized in such a way as to provide the user with the maximum guidance for conducting a science inquiry lesson. Emphasis has been placed on the use of simple material so that most of the events may be carried out with things that are found in everyday life or may be bought in local stores.

**When you as a parent**, use this book, you are actually becoming your child's or children's own private teacher! Isn't that exciting! All the statements concerning the teacher apply therefore, to you as well. The questions are there for each of the **exciting events** to be posed to the learner. The explanation is always there on each of the pages to give you the support you need in answering the questions. You can, of course, add your own questions if you want to go into more depth in each of the events.

**The use of exciting events** in the teaching of science is one of the best methods to arouse interest and curiosity. These **exciting events**, sometimes also called **discrepant events**, mind-capturing, or intuition-offending, are occurrences or happenings which go against what we usually think likely. Each of the events is set up in such a way that it poses a question to the student and asks him/her to come up with the explanation. There is evidence that students will remember science concepts longer when they were engaged in experiencing **exciting events**. This series of books is a collection of thoroughly tested **exciting events**. They can be used to start a lesson in almost any topic of science at the elementary or secondary level. They can also be used as reinforcement activities in the homes or as challenging problems for further inquiry. Each of the events is a focus for inquiry teaching, a most appropriate way of reflecting the true nature of science in the homes. The students are required to put into practice most of the science processes when engaged in inquiry.

**The science concepts** in this series of books are organized in such a way that it makes most sense:

**Book 1: Our Environment**, consisting of the chapters: Air, Flowing Air, Weather, Characteristics of Matter, and Chemicals in our Environment.

**Book 2: Energy**, consisting of the chapters: Forms of Energy, Heat, Magnetism, Static & Current Electricity, Light, and Sound.

**Book 3: Forces & Motion**, containing chapters: Forces Affecting Things, Forces and Principles in Space Science, Some Phenomena in Earth Science.

**Book 4: Living Things**, containing the chapters: Plants, and Human Biology.

In order to make it easier to find where certain topics are being dealt with, each of the books has its own **table of contents** in the front and an **index** in the back of the book. **Introductions** are placed in front of each book, so that each of the books can be used independently from each other.



## INSTRUCTIONS FOR PARENTS

Please follow these instructions for the Teaching Procedure in using **Turning Kids On To Science in the Home** as close as possible, so that your lesson will be most effective:

### 1. Presentation :

Present to the learner or involve the learner with the **exciting event** by describing or commenting on the names of objects and operations only and not mentioning the reasons for the occurrence. In other words, you may tell the student what you are doing and what materials you are handling, but not the reason why something is happening.

### 2. Interaction:

Ask the learner questions that eventually will lead him/her to the main reason for the occurrence. In doing this, the students will be engaged in science inquiry and actually practicing the science processes of observing, measuring, inferring, predicting, interpreting data, identifying and controlling variables, hypothesizing, and experimenting.

### 3. Involvement:

Participate the learner in similar (and simpler) **exciting events** or exciting activities, that are based on and illustrating the same science concept. This will reinforce the learning and retention of that particular concept. Students may work individually or together with you.

It is essential that the presentation of the **exciting event** or the involvement of the students in the event takes place under the following conditions. Think of giving the student: **INSIGHT!**

#### **IN = Arouse Interest**

The event should confront the student with a perplexing problem. It should be presented almost like the way a magician would do a magic act.

#### **SI = Use Simple Materials**

The event should be performed with materials that are familiar to the student, in other words use simple materials that can be found in daily life.

#### **G = Use all Gateways**

Use all the gateways into the brain, meaning students should have the opportunity to observe as well as carry out the events themselves. They should be allowed to totally experience the exciting event (by using all five senses).

#### **H = Hinge it with Examples**

When dealing with the concept underlying the event, examples and applications of the concept in our daily life should be mentioned to make it more meaningful to the student.

#### **T = Tie it all together with Joy and Enthusiasm**

Show genuine enthusiasm in presenting the puzzling event and don't be afraid to show your own enjoyment in the subject matter in general!

**ENJOY YOURSELVES !**

# BOOK 1

## OUR ENVIRONMENT

This book consists of five chapters dealing specifically with the properties of matter in our immediate environment. This includes the following:

1. The **air** around us in its stationary form. It occupies space, it exerts pressure, it expands when heated, it has weight, and it contains oxygen.
2. The **air** around us when it moves or **flows**. Flowing air exhibits properties that are unexpected, namely a lower pressure compared to stationary air, and the faster the flow, the lower the pressure exerted. This goes for all fluids.
3. The **weather** and all the variables influencing it, like: high and low pressures, the wind direction and velocity, the temperature and humidity, altitude and climate, and location on earth.
4. The **characteristics of matter**. This chapter deals with the molecular spacing of matter, cohesion and adhesion, surface tension, the three states of matter, and boiling and melting point.
5. The **chemicals** in our environment and how they behave. Acids and bases, salt formation, catalytic reactions, spontaneous combustion, substitution reactions, and electrochemical reactions are dealt with.

**DOING SCIENCE** IS

A LOT OF **FUN**



**Getting the hard-boiled egg back out of the milk bottle.**

**Showing that air exerts pressure and that it expands when heated.**

# CHAPTER 1

## WHAT ARE THE PROPERTIES OF AIR ?

### OBJECTIVES

**After dealing with and studying the concepts in this chapter, the students should be able to:**

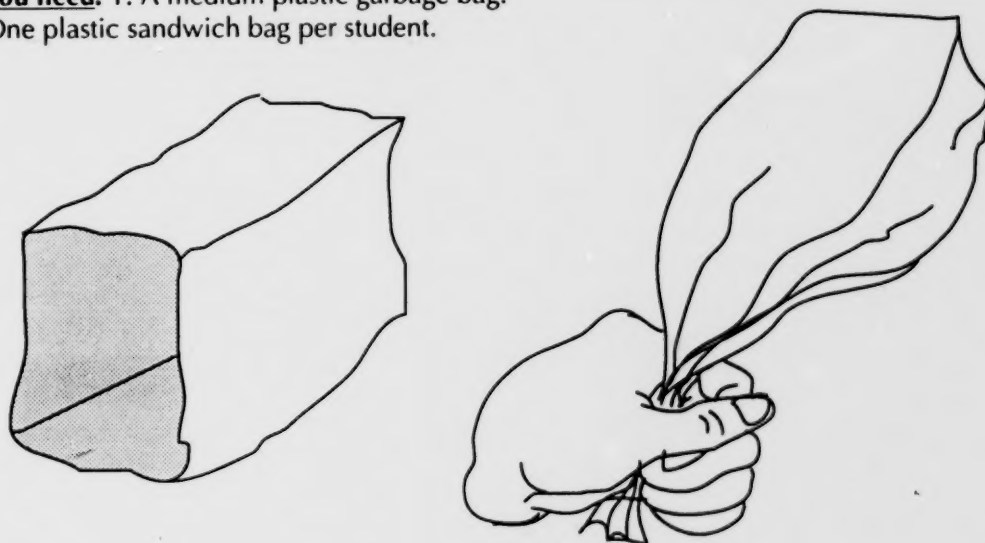
- a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. Explain in their own words which of the sub-concepts is determining the course of an event;
- c. Distinguish true from false statements concerning each of the sub-concepts;
- d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

**all in relation to the following sub-concepts:**

- Air exists all around us.
- Air occupies space.
- Air exerts pressure.
- Air expands when heated, and rises as a result.
- Air contains oxygen.
- Air has weight.

## 1.1.01. THE AIR CATCHER

**What you need:** 1. A medium plastic garbage bag.  
2. One plastic sandwich bag per student.

**How to do it:**

1. Take the medium size garbage bag, open its mouth and ask the students: "What is in the bag?" (Anticipated answer: 'nothing').
2. Move the bag now with two hands back and forth (like wanting to catch a bug in the bag), then quickly close the mouth of the bag with a twisting motion.
3. Ask the students: "What do I have in the bag now?"
4. Distribute the sandwich bags to the students and let them try to catch air in their own seats, without blowing into the bag.

**What questions to ask:**

1. What was filling the bags?
2. Can we catch air under the bench or behind the door? Is the air the same everywhere? How else can we fill the bag?
3. Would the material in the bag be the same if we blew in it? How can we keep the bag inflated? What would happen if we hit the inflated small plastic bag with the palm of the other hand?

**How to explain it:**

Air is found everywhere. The plastic bags may be filled with air above the table, under the table, behind the door or anywhere else with the same air. The bags can also be inflated by blowing in them, but then the bags would contain exhaled air, which has a higher percentage of carbon dioxide ( $\text{CO}_2$ ) and more water vapor.

When the filled bag is slammed between the two palms of the hands it will burst with a loud pop. This explosion is caused by the sudden expansion of the air rushing out of the torn plastic bag. **An example of this is a popping balloon.**

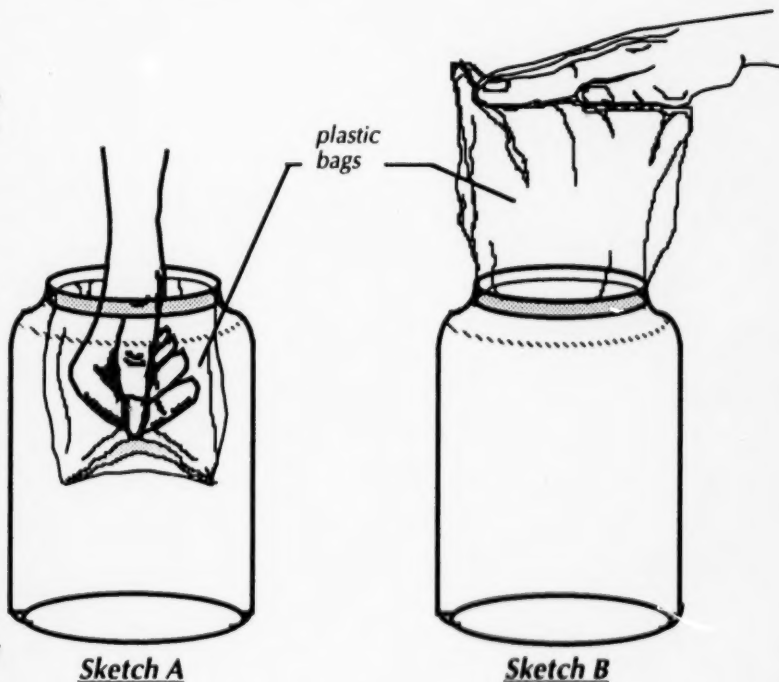


**1.1.02. THE BOTTLE AND THE BAG**

- What you need:**
1. One or two plastic sandwich bags.
  2. One or two large wide-mouthed glass jars (pickle jars).
  3. Masking or transparent adhesive tape.

**How to do it:**

1. Invert the bag over the mouth of the jar, blow a little air in the bag such that it stays inflated over the jar (see Sketch A).
2. Tape the bag air-tight against the jar.
3. Now ask one of the students to push the bag into the jar (without tearing it): It won't work!
4. Place another plastic bag inside another wide-mouthed jar (or use the same bag and jar) and let the edge of the bag hang over the jar rim (see Sketch B).
5. Tape it air-tight against the jar and let a student try and take the bag out of the jar (without tearing it): It won't work!

**What questions to ask:**

1. Before putting the plastic bag on the jar, ask: "What is inside the jar? Inside the plastic bag?"
2. What is holding the bag out of the jar? (When trying to push it in).
3. What is holding the bag inside the jar? (When trying to take it out).
4. How could we get the bag inside the jar without making a hole in it?

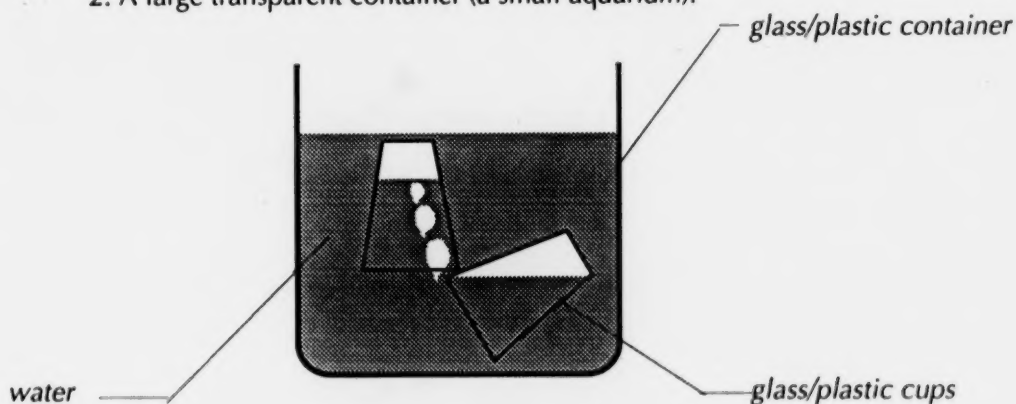
**How to explain it:**

It is the air occupying the space in the jar which kept the bag from going inside after it had been taped air-tight against the jar. In trying to push the bag in, the pressure increased (because the volume decreased) and this held the bag out.

When trying to take the bag out of the jar, the air pressure inside the jar decreased, because the volume increased, and this kept the bag inside. The outside air pressure kept the bag inside the jar. We encounter the first situation often when we try to fold up a plastic air mattress or inflatable plastic toy.

1.1.03. **POUR AIR UNDER WATER**

- What you need:**
1. Two glass or transparent plastic cups.
  2. A large transparent container (a small aquarium).

**How to do it:**

1. Fill the plastic or glass container about 3/4 full with water.
2. Hold one cup in each hand upside down and push them under water.
3. Fill one of the cups with water by holding it slanted and thus releasing the air bubbles (do not leave any bubbles).
4. Now we have one cup filled with water in the one hand, and one cup with air in the other (still under water).
5. Now push the cup with air a little lower than the other, and **pour** the air in the other cup by slowly slanting it (catch the air bubbles: see Sketch).
6. We can repeat this **pouring** from one cup into the other.

**What questions to ask:**

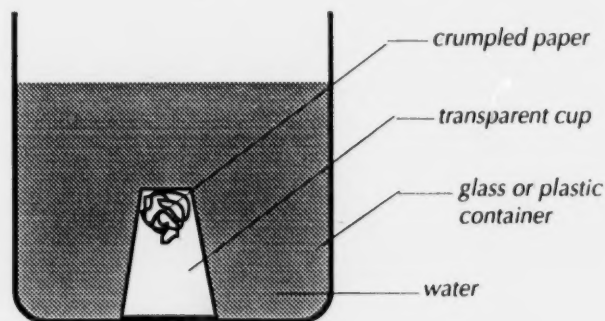
1. Before immersing the cups, ask: "What is in the beakers or cups?" (Anticipated answer: 'nothing').
2. At the time of immersing the inverted cups, ask: "Why doesn't the water enter the cups?"
3. Why do the bubbles rise and not sink?
4. Can the cup with water be held partly above the water level without letting the water run out of the cup?

**How to explain it:**

Air **occupies space** and also the space in the cups. At the time the cups were immersed under water, they were filled with air, and that is why the water could not enter the cups. By holding one cup slanted the air bubbles were free to escape and thus the water could take its place. Air is much lighter in weight than water and that is why air bubbles rise and not sink in water. The water-filled cup can be held partly above the water level without letting the water run out, because the atmosphere pressure is pushing on the water surface.

**1.1.04. KEEP PAPER DRY UNDER WATER**

- What you need:**
1. A dry glass or transparent plastic cup.
  2. A large beaker or transparent plastic container (large enough to fit a person's hand).

**How to do it:**

1. Fill the large container about 2/3 full with water.
2. Crumple a piece of dry paper and squeeze it to the bottom of the glass or plastic cup.
3. Invert the glass (making sure that the crumpled paper stays up in the cup) and immerse it completely under water, holding it as vertically as possible.
4. Take the cup back out of the water and let the water drip off (do not shake off!).
5. Take the crumpled paper out of the cup with a dry hand and let the students feel and check whether it is dry or not.

**What questions to ask:**

1. Before inserting the crumpled paper, ask: "What is in the cup?" (Anticipated answer: 'nothing').
2. Before immersing the glass under water, ask: "What else besides the paper is in the cup?"
3. While immersing the cup: "Why doesn't the water enter the cup?"
4. Why does the paper have to be crumpled?

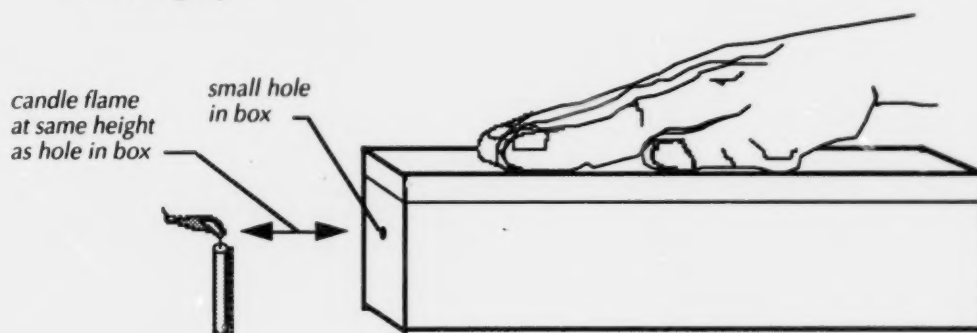
**How to explain it:**

**Air is space occupying.** The glass is therefore filled with air, no matter whether it is right side up or upside down. Besides the crumpled paper there was air in the cup. This is why the water could not enter the cup during the immersion process. The paper stayed therefore completely dry.

Applications of this characteristic of air can be found when people have to work under water. Air is then pumped in and around the area where the people are working, enclosed by a water-tight wall.

**1.1.05. THE EMPTY BOX CANDLE SNUFFER**

- What you need:**
1. One empty shoe box.
  2. A birthday candle & matches.
  3. Masking tape.

**How to do it:**

1. Show the open shoe box to the students and ask: 'What is in the box?' (Anticipated answer: 'nothing').
2. Make a small hole in the side of the long end of the box (about 1/2 cm in diameter) at the same height from the bottom as the candle length, and tape the top to the box.
3. Light the candle and place it about 5 cm away from the box in front of the hole (see Sketch).
4. Hit the box top with a sudden tap with the open hand (make sure that the hole and the center line of the box are in line with the candle flame).
5. The lighting and snuffing of the candle may be repeated by going points 3 and 4.

**What questions to ask:**

1. What was blowing the candle flame out?
2. What did tapping the box do to the volume of the box?
3. How far away can you hold the candle from the box and still blow it out?
4. What would happen to the flame if you pushed the box top in gently instead of giving it a sharp tap?

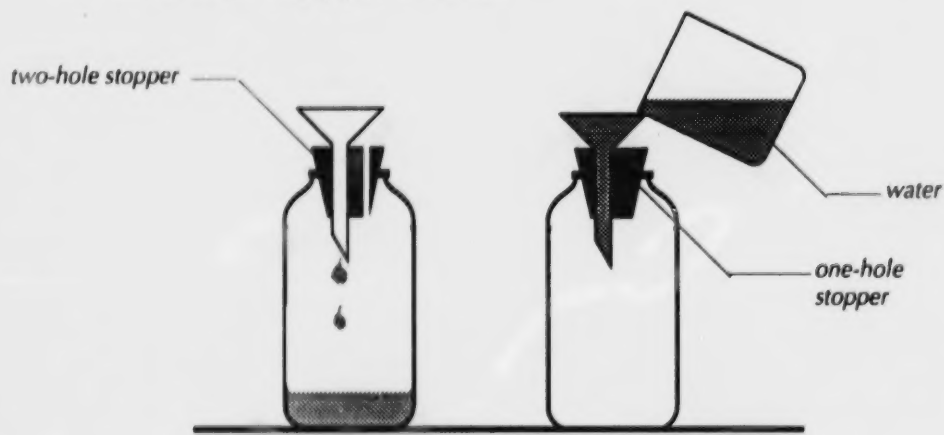
**How to explain it:**

The shoe box is **occupied with air** and by tapping the top of it, the air was forced through the little hole, blowing the candle flame out, just like when we pucker up our lips to blow out a candle. By tapping the box, the volume of it suddenly becomes smaller for a short moment and this action forces the air out. Pushing the box in gently is like blowing very lightly against the flame. This demonstration shows that air is **occupying all the space** around us, also in an 'empty' box.

1.1.06.

**THE REFUSING FUNNEL**

- What you need:**
1. Two identical glass or plastic funnels with narrow stem.
  2. One two-hole stopper & one one-hole stopper.
  3. Two identical empty jars or bottles.

**How to do it:**

1. Set up the funnels with the stoppers on the bottles as shown in the sketch above (do not tell that one of the stoppers has two holes).
2. Fill the funnels with water: in one the water will run through (2-hole stopper) and in the other the water will stay in the funnel.
3. Take the bottle with the 2-hole stopper by the neck and put casually the forefinger on the open hole, and pour water in the funnel: water refuses to run through.
4. Take the bottle with the 1-hole stopper, squeeze the stopper open and the water will run through.

**What questions to ask:**

1. Before pouring the water, ask: "What is in the bottle?"
2. Why is the water only running through in one bottle?
3. After step 3 of procedure: Why is this funnel now also refusing to let water through?
4. What is holding back the flow of the water?
5. Before doing step 4 of the procedure, ask: "How can we let the water run through this funnel? Are there any other ways?"

**How to explain it:**

The bottles were filled with air in the first place, in other words, **air took up space** in the bottle. In the bottle with the two-hole stopper the air can escape through the second hole and the water will run through. But in the bottle with the 1-hole stopper, there is no way for the air to escape and this will hold back the water.

An example of this phenomenon we find when trying to fill a perfume bottle with water or other liquid, or any narrow mouthed bottle with water by holding it under a large stream of water from the tap. There is only one passage way for the water to come in and for the air to go out, in other words, the air is blocking the way for the liquid to come in.

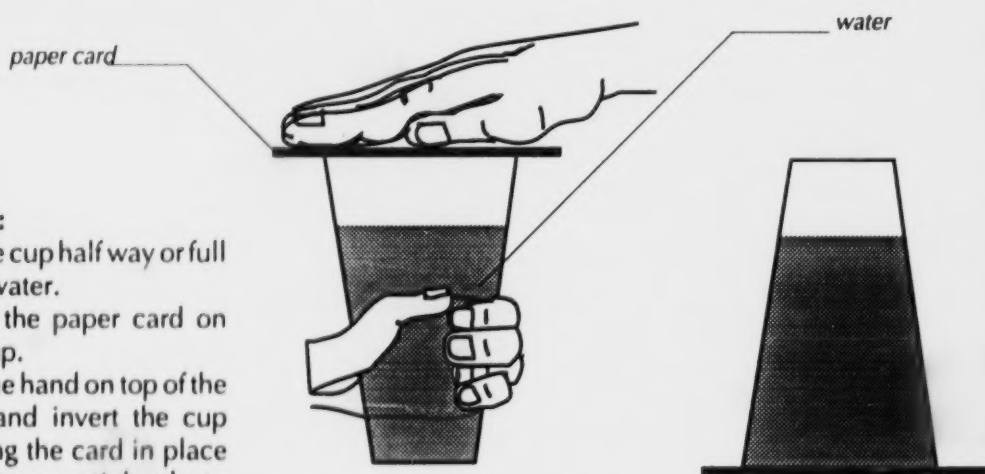


## 1.1.07. THE INVERTED GLASS OF WATER

- What you need:**
1. A transparent glass or plastic cup.
  2. A paper card (slightly larger than the mouth of the cup).

**How to do it:**

1. Fill the cup half way or full with water.
2. Place the paper card on the cup.
3. Put one hand on top of the card and invert the cup holding the card in place (do this over a sink or large container to catch any water drippings; also make sure that the hand holding the card is dry).
4. Take the hand that was holding the card slowly away.

**What questions to ask:**

1. Why does the paper have to be rather stiff?
2. Why do we have to make sure that the hand holding the card on the cup is dry? What will a wet hand do?
3. What is keeping the water in the inverted cup?
4. Can we hold the cup slanted without letting the water pour out?
5. Will we be able to do the same thing with other liquids? (f.i. alcohol, oil, carbonated drink, hot water, etc.?)

**How to explain it:**

When the cup is completely filled with water, there is no air left in the cup and thus no air pressure. The inverted cup can therefore hold the water up, because the **atmospheric pressure** is working against the under-side of the cup.

In case of a partially filled cup of water, we can explain it as follows: During the process of inverting, some of the water is dripping out, this increases the volume of the air pocket without increasing the amount of air, thus decreasing the pressure of the air pocket above the water. Again, the **atmospheric pressure** is therefore larger and thus holding the water inside the cup.

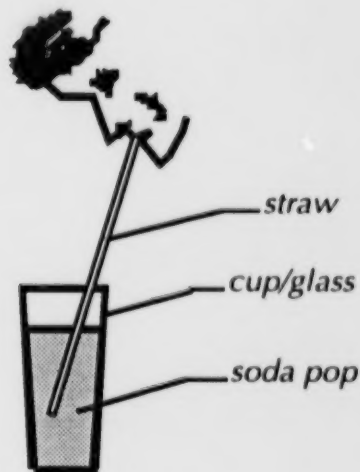
Alcohol and oil will also be held up inside the inverted cup, but the carbonated drink will not, because the carbon dioxide exerts pressure inside the glass above the liquid and prevents a partial vacuum from forming; so does hot water.

**1.1.08. THE STRAW DRINKING RACE**

**What you need:** 1. Two identical drinking straws (one punctured with a few needle holes over the whole length). 2. Two small cups and some soda drink.

**How to do it:**

1. Fill the two small cups halfway with soda pop.
2. Ask two students to come up and comment: "Who would be the better 'sucker'?", and give each of them a straw (one of them with holes in it, but **do not** mention this).
3. Let them start drinking (sucking) on the count of three.
4. Give another pair of students a turn to race (the one who has the straw with the holes always loses).

**What questions to ask:**

1. What makes the liquid go up the straw when we drink?
2. Why is it so hard to drink through a leaky straw?
3. What do we actually create when we suck through a straw?
4. Would we be able to drink through a straw if there was no air pressure around us?
5. Would an astronaut in space or on the moon be able to drink liquid through a straw?

**How to explain it:**

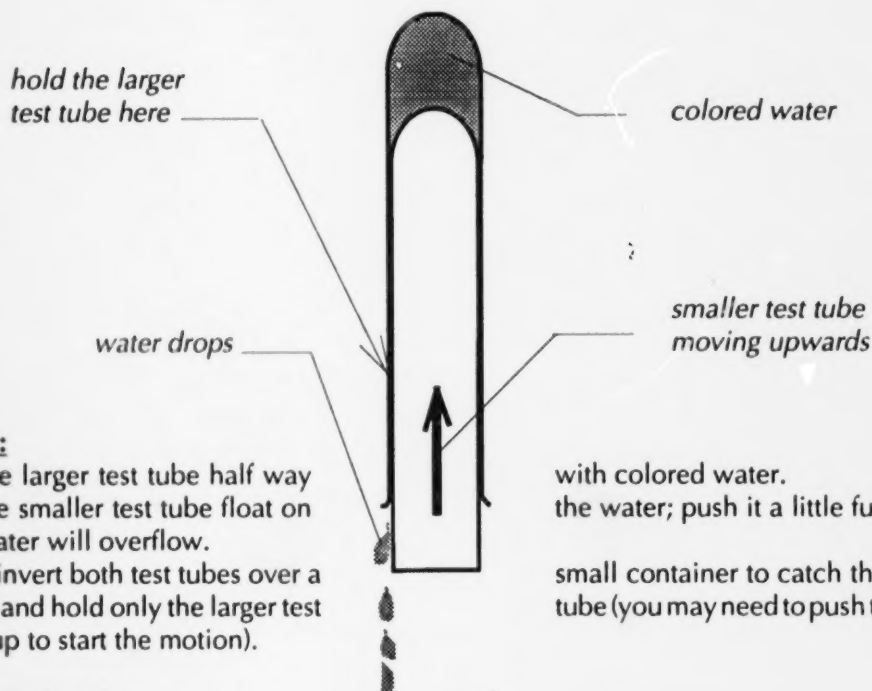
By sucking we are creating a **partial vacuum** or a **lower pressure** in the straw above the liquid that we drink. The higher pressure in the atmospheric air pushes the liquid up the straw in our mouth.

The student with the leaky straw sucks in air and thus cannot create a vacuum above the liquid, so the liquid is not pushed up.

If there were no air pressure in the atmosphere, we would not be able to suck liquids through a straw. If the mouth of an astronaut was connected to a straw through his space suit to an open cup with liquid on the moon surface, he would not be able to drink the liquid by sucking through the straw, because there is no pressure on the liquid surface that will push it up the straw. Astronauts have to push liquids from a plastic bag into their mouth to drink.

## 1.1.09. THE UPWARDS FALLING TEST TUBE

**What you need:** 1. Two test tubes, one just fitting into the other.  
2. A little colored water.

**How to do it:**

1. Fill the larger test tube half way
2. Let the smaller test tube float on the water will overflow.
3. Now invert both test tubes over a water and hold only the larger test tube up to start the motion).

**What questions to ask:**

1. What happened to the volume of the water after inverting?
2. What made the smaller test tube move upwards?
3. What would be the total force pushing the test tube upwards?
4. Would this 'falling upwards' also succeed with a much smaller test tube floating on the water of a much larger test tube and then inverting it? Why? Why not?

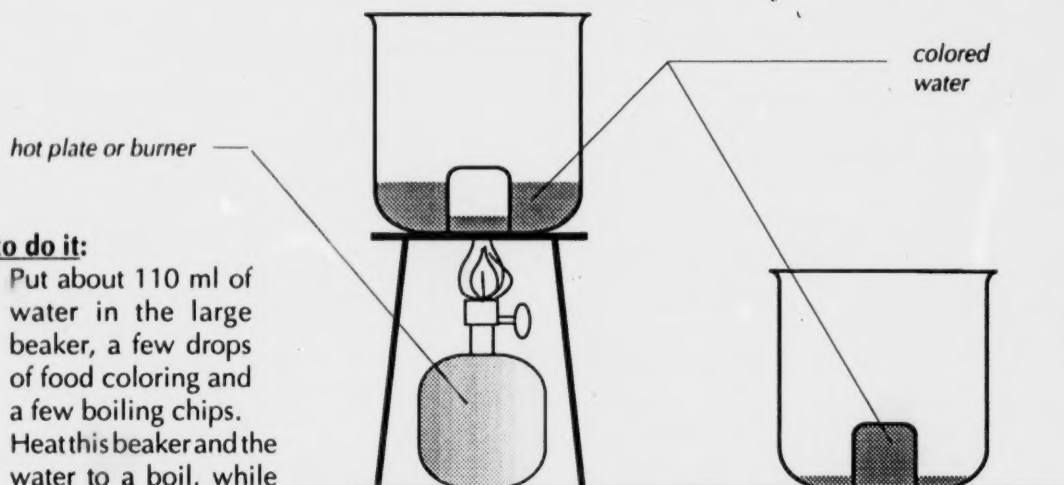
**How to explain it:**

The smaller test tube has to be pushed a little further into the larger one till the water overflows, so that no air will be left between the two test tubes. After inverting the set of test tubes, the water from the larger test tube drips out **decreasing the volume of the water**. Since there is no air above the smaller tube, the **outside air pressure** is pushing it up. The total force upwards is 1 Kg per cm<sup>2</sup>. For a test tube with about 1.2 cm diameter this upward force is about 1 Kg. This event of 'falling up' will not succeed with two test tubes that have a larger difference in diameter, because the air will be able to replace the dripping water and thus equalizes the pressure above and under the smaller test tube. Other thought questions would be:

- Would this event work on the surface of the moon?
- Would this event work in a pressurized satellite around the earth?

## 1.1.10. THE MYSTERIOUSLY RISING WATER (I)

- What you need:**
1. One small beaker (100 ml) & one large beaker (400 ml).
  2. One hot plate or burner and stand.
  3. Boiling chips and food coloring.

**How to do it:**

1. Put about 110 ml of water in the large beaker, a few drops of food coloring and a few boiling chips.
2. Heat this beaker and the water to a boil, while the small beaker is placed upside down inside the larger beaker.
3. Let the water boil for at least one full minute, taking care that the small beaker does not tip over.
4. Take the two beakers off the fire and let them cool to room temperature. Observe the water level in the small beaker.

**What questions to ask:**

1. What is inside the inverted small beaker before the heating?
2. What happens to the water when we boil it?
3. Why does the small beaker keep bobbing up and down?
4. What do the bubbles consist of?
5. Why does the water level rise in the small beaker?
6. What would happen if after the heating, we put a few drops of cold water on the small inverted beaker?

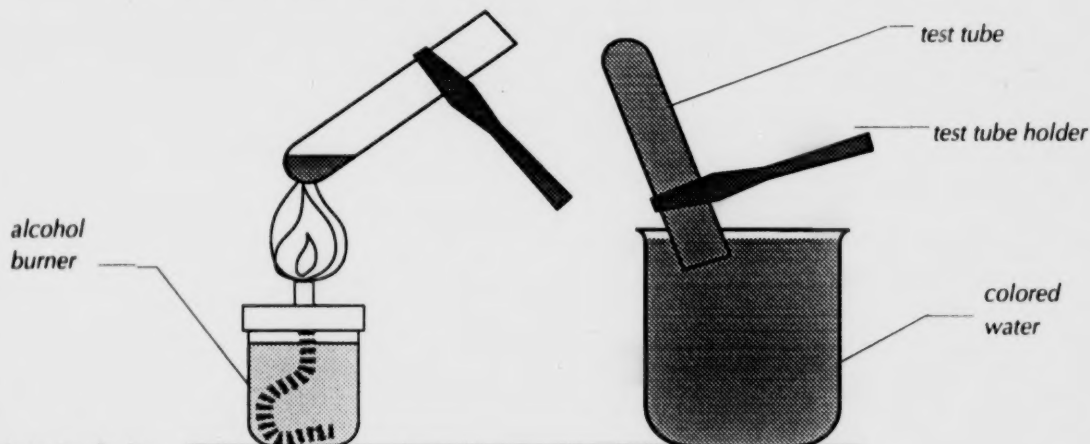
**How to explain it:**

By boiling the water, it is changing from the liquid state into the gaseous or vapor state. This water vapor is also formed under the inverted beaker and it replaces the air under this beaker. The longer we let the water boil, the more **air will be replaced by water vapor**. The cooling process makes this water vapor condense and turn back into water, thus reducing the pressure inside the small beaker. The water is therefore pushed up inside the inverted beaker by the higher atmospheric pressure. By letting a few drops of cold water drip on the inverted beaker, the cooling process is speeded up and thus also the rising of the water.



## 1.1.11. THE MYSTERIOUSLY RISING WATER (II)

- What you need:**
1. One test tube & test tube holder.
  2. One large beaker (400 ml) or other water container.
  3. One Bunsen or alcohol burner & food coloring.

**How to do it:**

1. Fill the large beaker with cold water and color.
2. Put a little water in the test tube (about 3 ml) and boil it (A).
3. After the water has been boiling vigorously for about 10 seconds, invert this test tube immediately in the colored water (making sure that the test tube mouth stays under water: see Sketch B).

**What questions to ask:**

1. What is in the test tube besides the water before heating?
2. What is in the test tube during the heating?
3. What happens during inverting of the test tube into the colored water?
4. What does water do when it is boiled?
5. What does water vapor do when it is cooled?
6. How did the temperature of the test tube change when it was inverted?
7. Why did the colored water rise in the inverted test tube?

**How to explain it:**

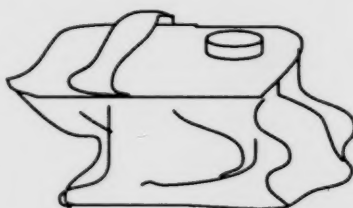
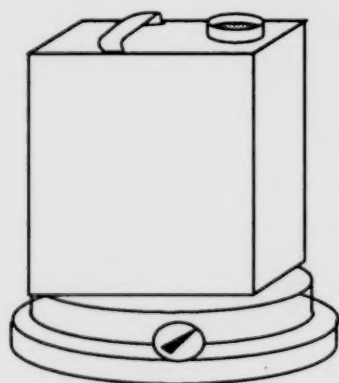
Before the heating, the test tube was filled with a little water and the rest was air. Water vapor was produced by boiling the water and this water vapor pushed out the air in the test tube (vigorous boiling of the water). After inverting the test tube in the colored cool water, the hot water from the test tube poured out into the large container, the test tube slowly cooled off, causing the water vapor to condense. This decreases the pressure inside the test tube and thus the water is pushed up the tube by the existing **atmospheric air pressure**.

Other very similar events are: **The Mysteriously Rising Water (I)** and **The Fountain in a Flask**. We encounter this kind of an event in daily life sometimes when, after boiling water or soup in a pan with a well fitting top, cooling the pan afterwards and trying to open the cover, only to find the cover to be sticking to the pan. To open this cover, try turning it to let some air in the pan. If this is still not successful, heating the pan again should develop steam and increase the pressure inside the pan.



## 1.1.12. THE COLLAPSING CAN

**What you need:** 1. One empty gallon (or 4-5 liter) can, or any other tin can that can be closed off air-tight. 2. A hot plate or burner and tripod.



*gallon can  
after cooling*

**How to do it:**

1. Put about 20 ml of water in the can (just enough to cover the bottom) and heat it over the hot plate or burner.
2. Let the water boil vigorously for about 2 minutes (vapors should come out of the can).
3. Take the can with the boiling water off the heat (don't burn your fingers - use gloves!) and immediately close off with the cap very tightly.
4. Let it stand upright on the table and cool off to room temperature, or for faster results: cool off with a wet towel.

**What questions to ask:**

1. What was in the can besides the water?
2. What happens when water is boiled?
3. What will the air in the can do when much water vapor is formed?
4. What would happen if we did not close the can very tightly?
5. What is the total force that is working on the outside of the can?

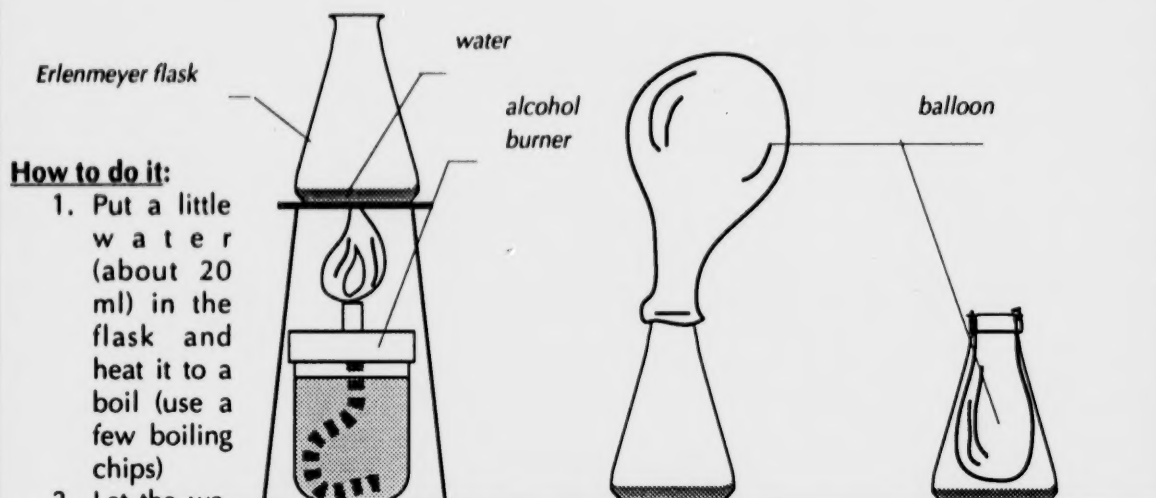
**How to explain it:**

Before heating, the can was filled with water and air. By boiling the water, it changed states, from liquid to gaseous state (water vapor). The water vapor or steam pushed the air that was inside, out of the can. In closing off the can with an air-tight cap, we are actually trapping the air out of the can: we are preventing it from going back into the can. The **cooling process condenses** the water vapor back to water. All the vapor which took up the interior space of the can before, is now turned into a few drops of water, which take up much less space. This causes the pressure to drop and the atmospheric pressure is therefore pushing on the can and crushing it.

The total force working on the outside of the can is the total of the can's surface area in  $\text{cm}^2$  multiplied by 1 Kg (=total Kgs) or the surface area in square inches times 14.7 lbs (=total lbs).

## 1.1.13. THE BALLOON IN THE FLASK

- What you need:**
1. An Erlenmeyer flask (150-200 ml).
  2. A round balloon with a large mouth (uninflated).
  3. A hot plate or burner and stand.

**How to do it:**

1. Put a little water (about 20 ml) in the flask and heat it to a boil (use a few boiling chips)
2. Let the water boil vigorously for at least one full minute.
3. Take the flask off the fire and immediately place the balloon with the mouth over the flask's mouth.
4. Let cool slowly at room temperature and observe the balloon being sucked inside out into the flask!

**What questions to ask:**

1. What is in the flask besides the water?
2. What is water doing if we boil it?
3. What is the steam doing to the air in the flask?
4. Why did the balloon go inside the flask?
5. Why did the balloon continue to expand inside the flask?

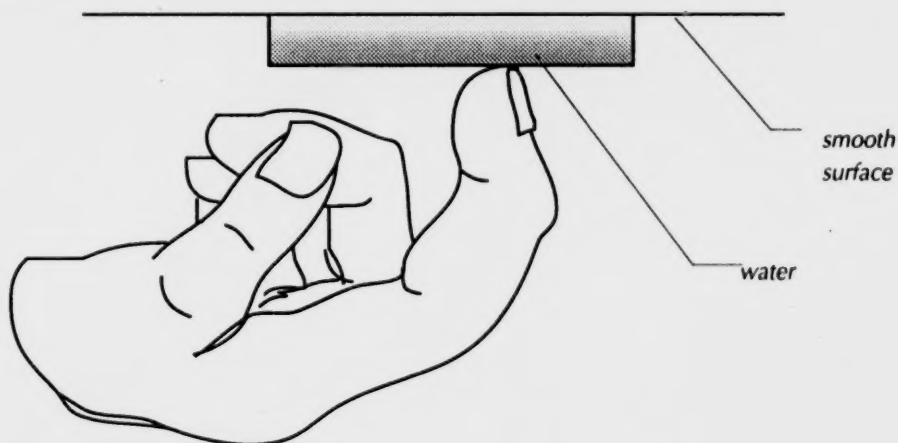
**How to explain it:**

By boiling the water in the flask, it was changed from the liquid state into the vapor state. Water vapor or steam is formed and this pushes the air that was originally present in the flask, out of the flask. The longer we let the water boil, the less air will be left in the flask. After the flask is closed off with the balloon, the air cannot get back into the flask. The cooling of the flask will slowly **condense** the water vapor and thus create a **partial vacuum** in the flask. This will cause the sucking in of the balloon and the **atmospheric air pressure** will further blow up the balloon inside the flask.

During the cooling of the flask and the sucking in of the balloon, care has to be taken that the balloon's mouth is not pinched closed (this will prevent the whole balloon from getting into the flask; only part will go in and probably burst).

**1.1.14. THE STICKING CUP OF WATER**

- What you need:**
1. A petri dish (or other shallow dish with smooth rim).
  2. A smooth surface, ceiling, or underside of a table.

**How to do it:**

1. Fill the petri dish brim-full with water.
2. Bring the dish to the smooth surface: push it against the surface making sure that there are no air bubbles left in it.
3. At this point make sure that the dish will stick to the surface, then ask a student to hold it up or do as if you need to get something and have to leave the dish.
4. Give the student permission to let go of the dish or say: "Maybe I can let go of the dish" (if holding it yourself).

**What questions to ask:**

1. Why do we need a smooth surface?
2. Why does the dish stick to the surface?
3. How much force is holding the dish up?
4. How heavy a dish can we stick to the surface?
5. How long will the dish keep sticking to the surface?

**How to explain it:**

By filling the dish completely full with water, there is no air left and thus there is **no air pressure** working down on the dish. The only force working down on the dish is **gravity** and thus the weight of the dish plus the water. The force holding the dish against the surface is equal to the air pressure of 1 Kg per  $\text{cm}^2$  of dish surface area. A dish with a 3 cm radius will have a force of about 27 Kg holding it up minus the weight of the water and the dish itself. Once the dish is sticking to the surface, it will stay up for quite a long time until some water evaporates and air seeps into the dish.

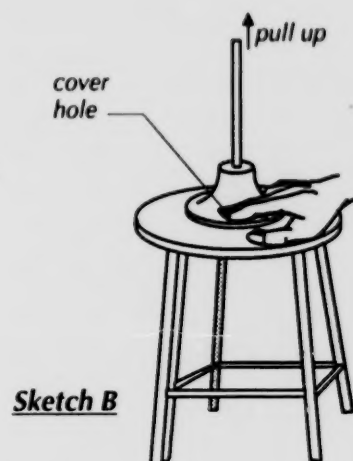
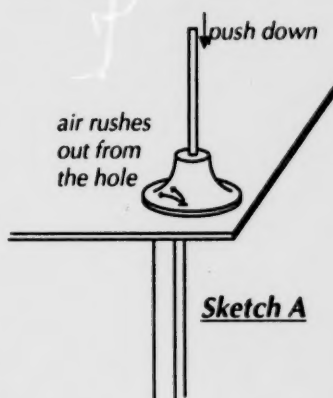
The water, in this case, acted as a seal preventing the air from coming into the dish. An application of this principle is when we wet suction cups with water to make them stick better to smooth surfaces.

## 1.1.15. THE BIONIC FINGER (I)

**What you need:** 1. One heavy rubber plunger (to unplug a sink).  
2. A stool or chair with a smooth seat.

**How to do it:**

1. Make a small hole in the plunger with a scissor's point.
2. Show the students the plunger and ask "What is under the plunger when I place it on the table?" (Anticipated answer: 'nothing').
3. Ask one of the students to come up and put his/her cheek close to the hole in the plunger.



4. Push the plunger in: air rushes out and blows against the cheek! AIR OCCUPIES SPACE! (See Sketch A). So there was something under the plunger.
5. Show the students the plunger on top of a stool.
6. Tell them that you possess a bionic finger and that you can hold down the plunger against the stool with one finger.
7. Push down on the plunger and hold it down with one finger covering the hole (a wet finger will work better), and ask a student to come up and pull the plunger up (see Sketch B). **The whole stool will stick to the plunger and be lifted!**

**What questions to ask:**

1. What was under the plunger?
2. What was helping my finger to keep the plunger down?
3. How much force is pressing down on the plunger?
4. How heavy can the stool be and still be lifted up?

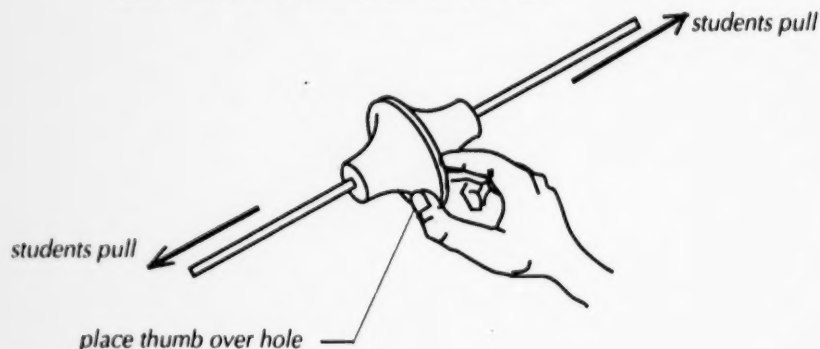
**How to explain it:**

There was air under the plunger and it rushed out when it was pushed in. When holding the plunger down with one finger, the hole was covered and this prevented the air from coming back in under the plunger, causing a lower pressure under it. A moist finger works better to plug the hole, because the water acts as a seal.

The force holding down the plunger is equal to the surface area of the plunger multiplied by 1 Kg (about 75 Kg for a plunger with a 10 cm diameter).

## 1.1.16. THE BIONIC FINGERS (II)

**What you need:** 1. Two heavy rubber plungers (to unplug a sink).  
(One of them with a small hole in it).

**How to do it:**

1. Ask two students to come up and push the two plungers against each other.
2. Ask them now to pull them apart (can be easily done).
3. Tell the students now that you have **bionic fingers** to keep the two plungers together.
4. Let the students push the two plungers together again and this time hold the plungers with thumb and forefinger, making sure that you cover the hole with your thumb (a wet thumb works better).
5. Now let the students try to pull the plungers apart (most likely the wooden handle will come off first!).

**What questions to ask:**

1. Why was it so easy to pull the plungers apart before I held them?
2. What did actually hold the plungers together?
3. Did I have to hold the plungers in a special way?
4. How much force was keeping the two plungers together?
5. Would larger or smaller plungers stick together better?

**How to explain it:**

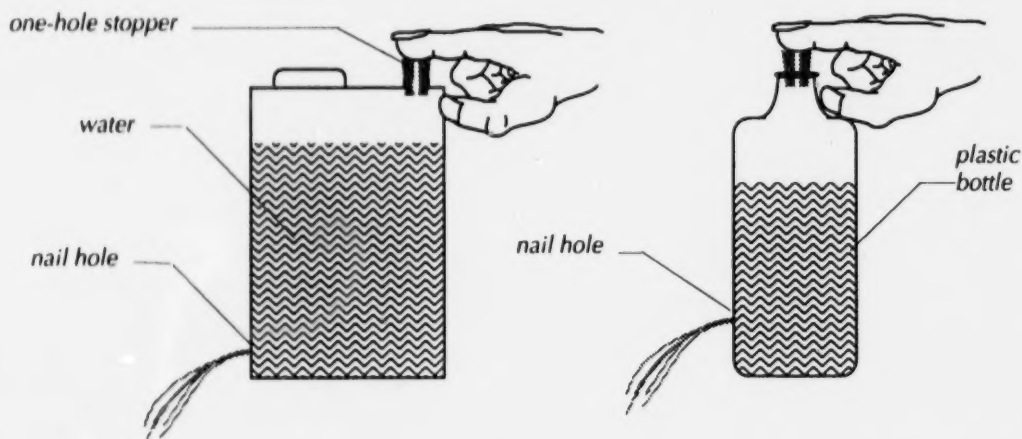
The plungers were quite easy to separate before holding them together, because there was a hole in one of them, allowing the air to come inside between the two plungers. By covering the hole, the air was prevented from coming in (water on the finger acts as a seal) and when the students tried to pull them apart, the **volume increased** between the plungers, thus **decreasing the pressure**. It was again the **atmospheric air pressure** that was holding the two plungers together.

The total force that was holding them together can be calculated from the total surface area of the two circles multiplied by 1 Kg (about 150 Kg for plungers with a 10 cm diameter). A similar experiment was done with large steel half-spheres, where the air was sucked out of them, and five horses pulling on each side could not take them apart: Maagdenburg spheres (performed in Maagdenburg, Netherlands).



**1.1.17. STOP THE LEAK**

- What you need:**
1. An empty can or plastic bottle.
  2. A one-hole stopper fitting the neck of the can or bottle.

**How to do it:**

1. Punch a hole in the side near the bottom of the can or bottle with a small nail.
2. Fill the can or bottle with water and show the leaking container.
3. Ask: "How can I stop the leak without wetting my finger?"
4. Put the one-hole stopper on the can or bottle and cover the hole with one finger: the leak is stopped!
5. Release your finger from the stopper: leak will start again.

**What questions to ask:**

1. Why did the water stop flowing out of the can?
2. How could we stop the leak without the one-hole stopper?
3. Does the water stop flowing immediately after the hole is covered?
4. How does the air pressure inside the can compare with the atmospheric air pressure after the water stops flowing?
5. What is it that we prevent from entering the can by covering the hole?

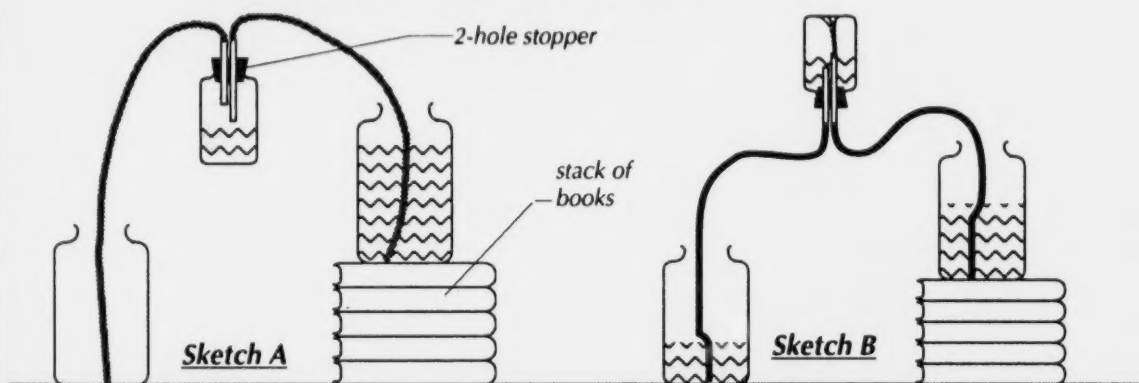
**How to explain it:**

The water does not stop flowing immediately after covering the stopper, but it still keeps dripping out of the can for a while. This increases the volume of the air pocket above the water. The amount of air stays the same because air is prevented from coming into the hole in the stopper. **The increase in volume causes a decrease in pressure (Boyle's Law).** The outside atmospheric air pressure pushes against the water and prevents it from flowing out.

This is why we always punch two holes in a can of evaporated milk in order to pour the milk out or in a can of juice to get the juice out. Also with a gallon frying-oil can, it usually is recommended to punch a hole in a corner opposite the pouring spout. This hole will allow air to enter the can while oil pours out. It will promote a smooth flowing of oil out of the can.

## 1.1.18. THE PERPETUAL FOUNTAIN ?

- What you need:**
1. One medium size jar and two large bottles.
  2. A 2-hole stopper fitting the jar, 2 glass tubes (the longer one drawn to a point at one end).
  3. Two lengths of rubber tubing (about 30 cm).

**How to do it:**

1. Push the two pieces of glass tubing through the 2-hole stopper such that the one with the point extends farther than the other (see Sketch).
2. Connect the two lengths of rubber tubing to the glass tubes.
3. Fill one of the two large bottles full with cold water and set up the flask and the two bottles as shown in Sketch A (Hold the jar).
4. Pour about 100 ml of water in the jar and insert the stopper tightly.
5. Invert this jar, making sure that the two rubber tubes stay in the two bottles (the end of the tube in the bottle with water should stay under water at all times).

**What questions to ask:**

1. What was the first thing that happened after inverting the jar?
2. What happened to the volume of the air pocket above the water in the jar as the water poured in the empty bottle?
3. Why was the water drawn up into the jar?
4. Why does the water-filled bottle have to stand higher than the other?
5. How can we make the fountain flow harder or slower?

**How to explain it:**

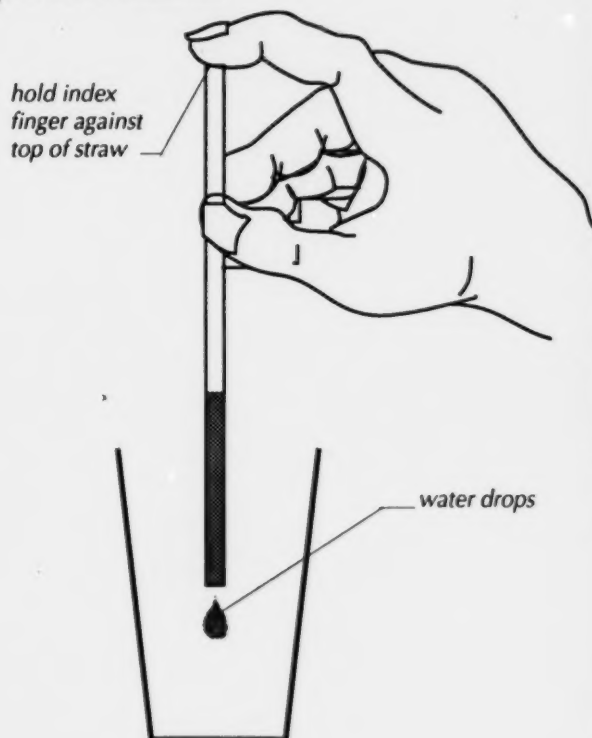
The water in the jar was needed to 'prime' the **siphoning** action. Immediately after inverting the jar, the water ran down and out into the empty bottle. This caused an increase in volume of the air pocket above the water in the jar, thus decreasing the pressure. This lower pressure caused the sucking up of the water from the water-filled bottle. In other words, the atmospheric air pressure is pushing the water up into the jar. The larger the difference in height of the water levels in the two bottles, the stronger the flow of water. As soon as the water levels are the same height in both bottles, the water flow will stop. This is the same principle of the siphon, except that here we can actually see the flow of the water in the flask - a transparent siphon!

## 1.1.19 TRANSFER WATER WITH A STRAW

- What you need:**
1. One drinking straw for each group of three students.
  2. Two small cups for each group of three students.

**How to do it:**

1. Divide the class in groups of three students.
2. Provide each group with one straw and two cups.
3. Let one student hold a water-filled cup, another an empty cup and let the third transfer the water from one cup into the other cup.
4. Ask the students how they can do this without tilting the cups.
5. Demonstrate how the water can be held in the straw:
  - dip the straw vertically in the water-filled cup;
  - hold forefinger against top end of straw and lift;
  - move straw with the water in it over the empty cup and release finger: water drips out!

**What questions to ask:**

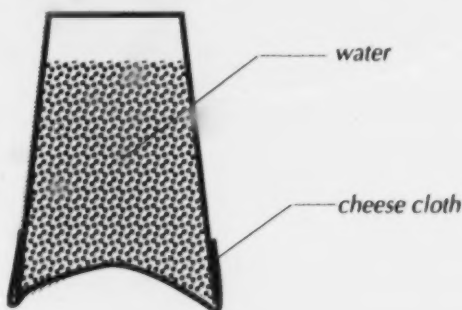
1. How can we transfer the water without tilting the cups?
2. How can we hold water in the straw without sucking on it?
3. What holds the water in the straw when your forefinger is closing off the top end of the straw?
4. What happens if we try to hold the water in the straw and not close the top end of the straw tightly?
5. What is prevented from coming in the straw at the end where our finger is pressing?
6. What is holding the water back if we close the top end of the straw with our finger before immersing it in the water?

**How to explain it:**

By closing off the top end of the straw with our forefinger, we prevent the air from coming in. Some water will drip out of the lower end of the straw, enlarging the volume of the air pocket above the water and thus creating a lower pressure inside the straw. The outside **atmospheric pressure** is holding the water up in the straw. When the finger is released, air is allowed to enter and the pressure is equalized.

## 1.1.20. THE WATER TIGHT CLOTH

- What you need:**
1. A drinking glass.
  2. A piece of cheese cloth or bandage gauze (or any other thin cloth) large enough to cover the mouth of the glass.

**How to do it:**

1. Place the piece of cheese cloth over the mouth of the glass and fill the glass half way or full with water by pouring the water right through the cloth.
2. Wet the edges of the cloth by dipping it in the water (make sure that the whole piece of cloth is wet).
3. Place the cloth now back over the mouth of the glass and push the fringes against the side of the glass.
4. Put the palm of one hand against the glass' mouth; with the other hand hold the bottom part of the glass without touching the cloth and invert.
5. Let go of the first hand: cloth and water will stay up in the glass!

**What questions to ask:**

1. Why would this not work with a dry cloth?
2. Why does the wet cloth cling to the sides of the glass?
3. Why does some water flow out of the glass in the beginning?
4. Why does the water stop flowing out?
5. What is keeping the water and the cloth up?
6. Can we hold the glass slanted or sideways without letting the water flow out?
7. What shape does the cloth take when we hold the glass vertically upside down?

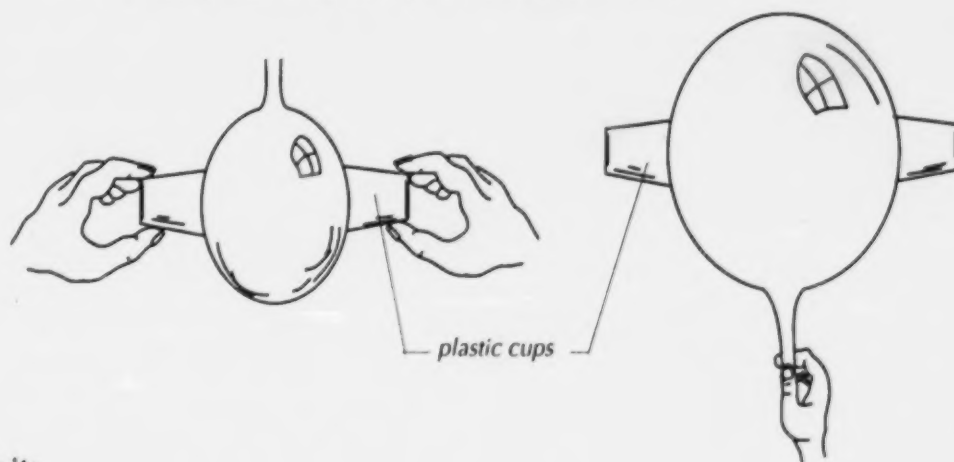
**How to explain it:**

The cloth needed to be wet with water so that it could **adhere** to the sides of the glass (adhesive forces between water and cloth, and water and glass). During the process of inverting, some water poured out because the cloth is porous, but this caused an increase of the air pocket volume above the water, which in turn **reduced the pressure** inside the glass. This demonstration can also be used to show the **cohesive forces** between the water molecules, as a film of water molecules is formed - showing **surface tension** - in the little pores of the cloth. Surface tension can be broken by touching the surface, shaking the glass, holding it slanted, or by adding a drop of soap to the surface, and all the water will pour out!



## 1.1.21. THE CUPS AND THE BALLOON

- What you need:**
1. An uninflated round balloon.
  2. Two small plastic or glass cups (with a smooth rim).

**How to do it:**

1. Blow up the balloon to about one-third way.
2. Tell the students that you will hold the two cups against the sides of the balloon and blow it further up.
3. Hold one cup in each hand, hold the cups against opposite sides of the balloon (while the balloon is in the mouth) and blow further (until about twice the size).
4. Let go of the two cups (they will stick to the balloon; if not, clean the cup rims) and hold the balloon in one hand by the mouth (a variation would be to make a face of the balloon with the two cups as the ears).
5. Show the students that the cups are not glued to the balloon by releasing the air slowly out of the balloon (the cups will fall off as the balloon gets smaller).

**What questions to ask:**

1. Why did the cups stick to the balloon?
2. Did the air pressure in the balloon have anything to do with it?
3. How does the volume of the cups change from stage A to stage B?
4. What does the pressure inside the cups have to be to stick to the balloon, compared to the atmospheric pressure (in stage B)?
5. How much larger does the balloon have to be in stage B compared to stage A for the cups to stick to it?

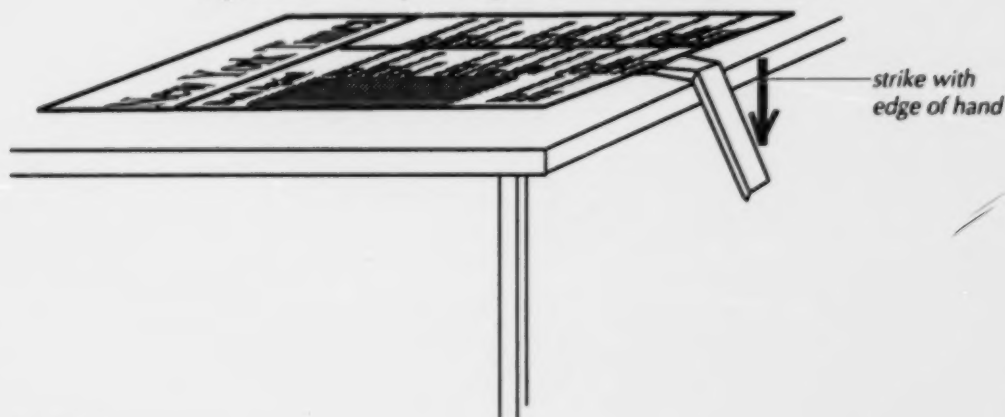
**How to explain it:**

Because of the increase in curvature of the balloon or actually a flattening of it from A to B, the volume in the cups increased, thus causing the **pressure to decrease**. The air pressure inside the balloon had nothing to do with the sticking of the cups to the balloon. The rubber of the balloon was also pressing against the rim of the cup and the cups were held there because of **friction** between the rubber and the cup's rim.



## 1.1.22. THE HEAVY NEWSPAPER

- What you need:**
1. One or two full sheets of an ordinary newspaper.
  2. A stick of pine wood (.3x3x75 cm or 1/8"x1"x2")  
(a piece of wood paneling or old thin ruler is excellent).

**How to do it:**

1. Place the stick on a table with a smooth surface and let it protrude over the edge about 8 cm or 3 inches.
2. Ask: "What will happen if I hit this protruding end of the stick?" (Anticipated answer: 'Stick will fly up').
3. Strike it and let the students catch the flying stick.
4. Place the stick back on the table like in point 1, and cover it with the newspaper flush with the edge of the table.
5. Ask "What do you think will happen now if I hit it again?" (Anticipated answer: 'The paper will fly up' or 'paper will tear').
6. Smooth down the paper with your left hand and strike the protruding end of the stick with your right hand (a sudden sharp blow with the edge of the palm): stick breaks!
7. By pulling the stick out another 8 cm after breaking, the cycle of smoothing the paper and breaking (point 6) may be repeated.

**What questions to ask:**

1. What did I do with my left hand?
2. Why was it necessary to smooth the paper before hitting?
3. What would happen if the protruding end of the stick was slowly pushed down?
4. How much weight was actually holding the stick down?

**How to explain it:**

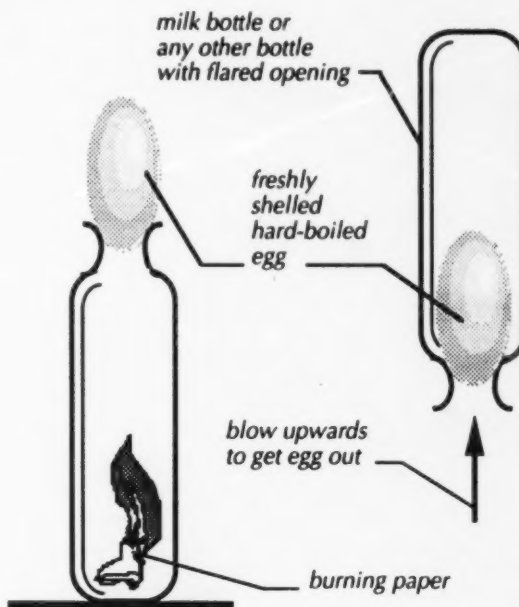
By smoothing the paper down, there was almost no air under it, but a whole column of air exists above the paper, pushing down on the paper with the **atmospheric pressure**. This is about 1 Kg/cm<sup>2</sup> (14.7 or rounded 15 lbs per sq. in.). The total weight or force pushing down on a 60 x 80 cm or 20" x 30" paper is roughly: 60 x 80 x 1 Kg = 4800 Kg, or 20 x 30 x 15 lbs = 9000 lbs, which is close to the weight of two large station wagons! It is therefore impossible to lift it with the thin stick! It is also the **inertia** of the air column that makes the stick break. A confident hard blow with the edge of the hand is required, but by all means: **avoid hitting the edge of the table!**

## 1.1.23. THE EGG AND THE MILK BOTTLE

- What you need:**
1. One hard-boiled egg.
  2. One empty glass milk bottle (or 1/2 l wine carafe).

**How to do it:**

1. Peel the shell off from the hard-boiled egg and place the egg on the mouth of the milk bottle.
2. Ask what will happen if I put a burning piece of paper in the bottle and place the egg back on the bottle?" (Anticipated answer: 'egg might jump off', 'fire goes out', 'the bottom of the egg will get black', 'the bottle might crack', etc.)
3. Burn a small piece of paper, lift the egg up, put the burning piece of paper in the bottle and place the egg immediately back on the bottle's mouth (egg dances on the mouth for a bit and then will be sucked into the bottle).
4. Ask question number 4.
5. To get the egg out of the bottle whole: invert the bottle and let the egg fall in the bottle neck, blow a short spurt of air up into the inverted bottle and catch the falling egg.

**What questions to ask:**

1. Why did the egg get pushed inside the bottle?
2. What did the burning paper do to the air inside the bottle?
3. What did the egg do before it went into the bottle? (Observe!)
4. How can we get the egg out of the bottle without cutting it up?
5. Is there another way to get the egg out whole?

**How to explain it:**

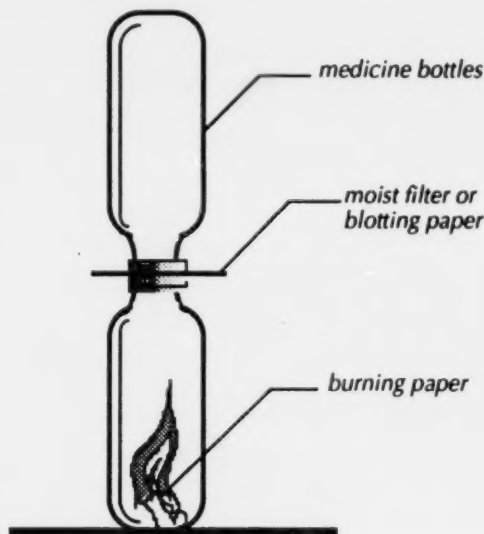
The burning paper is heating the air in the bottle and expanding it, and this is why the egg was vibrating/dancing before it was sucked into the bottle. Some of the air slipped under the egg out of the bottle and so there was less air, and thus **less air pressure** in the bottle. An added cause for decreasing the pressure inside the bottle is, that the burning of the paper took away the oxygen of the remaining air, turning it into  $\text{CO}_2$  and water vapor. The latter condensed against the cold bottle. Another way to get the egg out is, to warm the bottle while the egg sits in the bottle neck.

## 1.1.24. THE TWO BOTTLES IN LOVE

**What you need:** 1. Two identical bottles with thick smooth rims (medicine bottles).  
2. A piece of filter paper or blotting paper.

**How to do it:**

1. Soak the filter/blotting paper in water and place it over one of the bottles.
2. Twist a small piece of dry paper and make sure that it will fit through the mouth of the other bottle.
3. Burn this twisted piece of paper, put it in the open bottle and immediately cover this bottle with the filter-paper-covered bottle.
4. Press the top bottle for a few seconds longer on the lower one (until the flame of the burning paper is completely extinguished).
5. Now lift the two bottles up by holding on only to the top bottle.
6. Hold both bottles, invert the set, and let go of the lower bottle.

**What questions to ask:**

1. What did the burning paper do to the air in the bottle?
2. Why did the filter paper have to be soaked in water?
3. Why did the two bottles stick to each other?
4. Would the bottles stick to each other without the filter paper? Why?
5. How long will the two bottles stick to each other?

**How to explain it:**

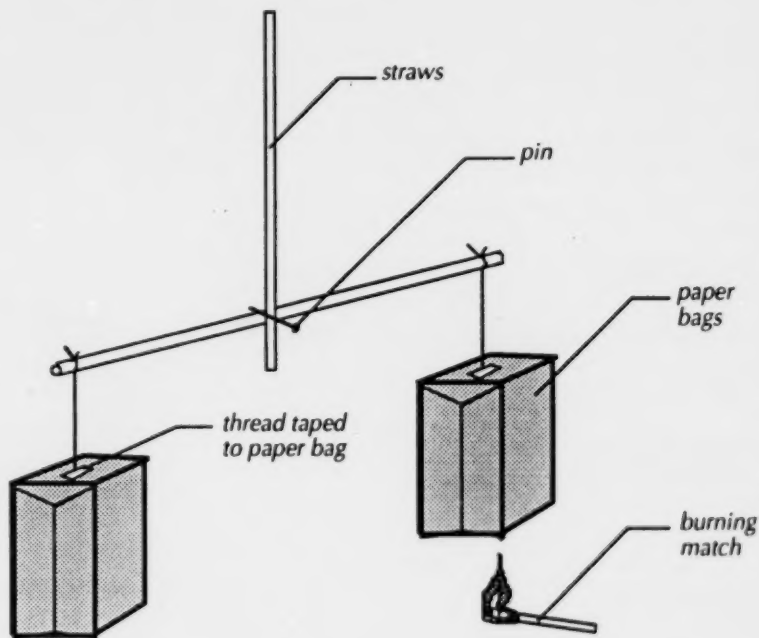
The burning paper heated up the air in the open bottle, which caused the air to **expand**. Thus some of the air in this bottle escaped. By covering this bottle immediately with the other bottle, the escaped air was trapped outside. The **air pressure** outside the bottles is keeping the set pressed together. The moist filter paper functions as a seal between the two bottles making them almost **airtight**. Without this filter paper, the air would seep between the two bottles and the trick will not work. The two bottles will stick together as long as the pressure inside is lower than the atmospheric pressure. Slowly air will seep in through the filter paper and as soon as the air pressures inside and outside the bottles are equalized, the bottles come apart.

## 1.1.25. THE INVERTED PAPER BAG BALANCE

- What you need:**
1. Two small identical paper bags.
  2. Two drinking straws and a pin.
  3. Two short lengths of thread, tape and matches.

**How to do it:**

1. Open the two small paper bags, invert, and attach the thread to the center of the bottom with a piece of tape.
2. Hang the two bags upside down on the ends of one of the straws, and balance this on a pin attached to the other straw as shown in the sketch (make sure that the straws move freely around the pin and test whether the horizontal straw will return to this position after pushing one side down).
3. Let one of the students hold the vertical straw, strike a match and hold the flame under one of the bags (be careful not to set the bag on fire).
4. This bag moves up. Take the flame away and the equilibrium is restored (both bags will be in balance again).
5. Hold a flame under the other bag and this side will now move up.

**What questions to ask:**

1. What is in the bags?
2. What is air doing if it is heated?
3. Why did the heated bag move up?
4. What happened after the flame was taken away from under the bag?
5. In which direction does heated air move?

**How to explain it:**

The flame under the bag heats up the air in the bag and **expands** it. This leaves less and lighter air in the bag. This lighter air pushes under against the bag and the bag moves up. When we take the flame away, the warm air cools down and slowly the balance of the two bags is restored.

This principle of making air lighter by heating is applied in **hot air balloons**. Air inside the balloon is heated, it expands and becomes lighter than the atmospheric air surrounding it and the balloon is pushed up by the lighter air (compared to the surrounding atmospheric air). The larger the balloon, the larger the force upward and thus the more weight it can lift.

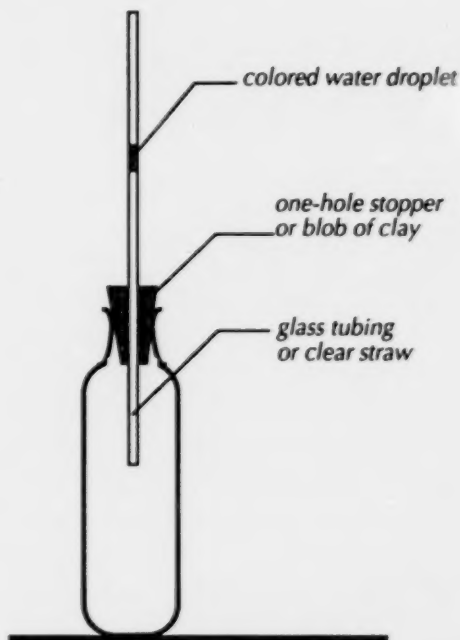


1.1.26. **SQUEEZE THE GLASS BOTTLE ?**

- What you need:**
1. An empty glass bottle.
  2. Glass tubing (about 30 cm) in a fitting 1-hole stopper, or a clear straw & clay.
  3. Water and food coloring in a small beaker.

**How to do it:**

1. Color a few milliliters of water with food coloring in the beaker.
2. Dip the end of the glass tubing/straw in the colored water and close the other end off with a finger. Take the tube out of the water, hold the tube horizontal and let the water drop ride in the tube until close to the stopper/blob of clay. (Close off the end again with the finger).
3. Place the stopper in the bottle neck and insert tightly (water drop will move up some).
4. Mark off the position of the water drop with a grease pencil, masking tape, or rubber band.
5. Hold bottle in both hands: what happens to the water drop?
6. Let the bottle stand on the table: what happens to the water drop?
7. If glass tubing and a rubber stopper are not available, molding clay and a clear straw may be used in their place - make sure that the clay is pushed airtight against the bottle & straw.

**What questions to ask:**

1. What is in the bottle?
2. Why does the water drop not slide down into the bottle?
3. Why does the water drop move up when inserting the stopper?
4. What made the water drop move up when the bottle was held?
5. How can we get the water drop to move down the tube?

**How to explain it:**

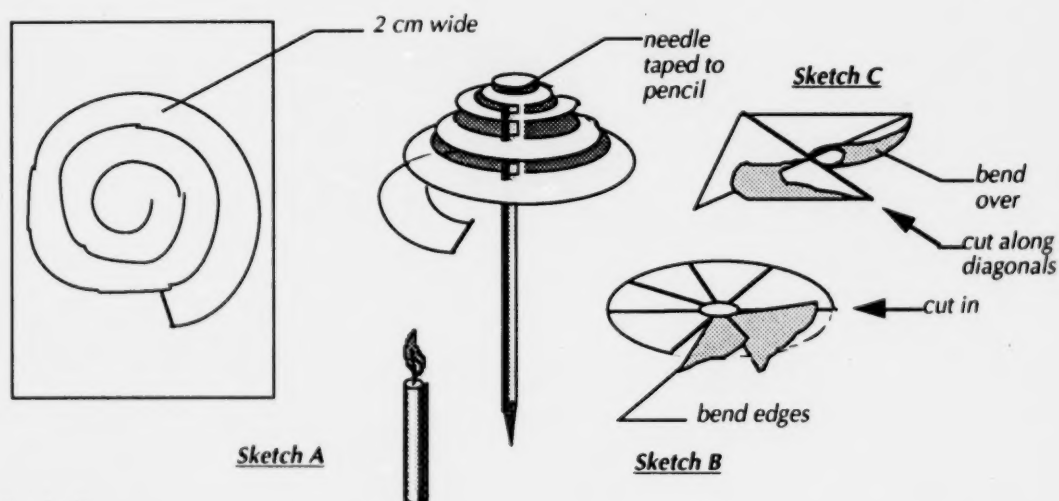
The 'empty' bottle is of course filled with air. In closing off the bottle with the stopper and tube, the water drop was pushed upwards by the air. It is because of the presence of air inside the bottle that the water drop in the tube cannot slide down by itself. It is actually held up in the tube by the air.

By holding the bottle in our hands, our body heat is warming up the bottle, which in turn warms the air. This **air expands** and pushes the water drop up the tube. By cooling the bottle with cool water and blowing against it, the water drop can be made to move down the tube, because the cooling makes the **air contract**.



## 1.1.27. PAPER MERRY-GO-ROUND

- What you need:**
1. Two (5" x 8") paper cards.
  2. A needle or pin, masking tape, scissors.
  3. A pencil or straw, a lamp or candle and matches.

**How to do it:**

1. Draw a spiral on the paper card of about 1 cm width and cut out the spiral with scissors following the line (Sketch A).
2. Tape the needle or pin to the pencil or straw with its point up.
3. Balance the paper spiral on the needle point and hold it about 10 cm above a lit candle or lamp: the spiral turns!
4. Other types of merry-go-rounds can be made from paper cards or light paper (construction paper) (see Sketch B & C).
5. Have a contest on *who the best paper merry-go-round can produce*

**What questions to ask:**

1. What does the burning candle do to the air?
2. What will heated air do?
3. What does a windmill need for it to turn?
4. Why did the spiral turn?
5. Can we make other paper cut-outs that will spin?

**How to explain it:**

The lamp or burning candle was the source of heat which heated the air. Hot air takes up a larger volume than cold air and is therefore lighter in weight. Thus **hot air rises** and by holding the paper spiral in this stream of air, it flows along the spiral and makes it turn.

Examples that are based on this same principle are the windmills, which only turn when there is a wind blowing. The air stream here, however, is flowing in a horizontal direction. The air stream which was moving the paper spiral moved in a vertical direction. Other paper cut-outs are drawn in figure B and C, which will also spin in a stream of air.

The needle point is the center point of rotation and it serves as a near frictionless set up for the rotation of the object. A very slow moving airflow would therefore be detectable.

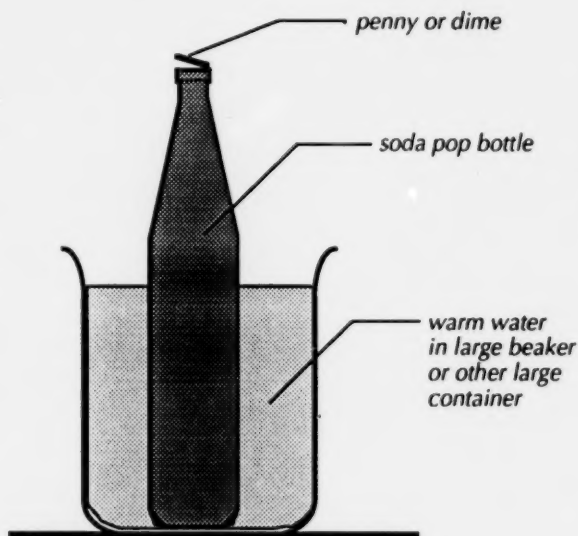
## 1.1.28.

## THE DANCING PENNY

- What you need:**
1. One empty bottle with a narrow neck.
  2. One large beaker or container for warm water.
  3. A penny or dime, or other small coin.

**How to do it:**

1. Moisten the opening of the bottle and place the penny or dime flat on the bottle mouth.
2. Fill the large beaker with hot water (not steaming, so that it would look like cold water; if possible fill this container before doing the demonstration).
3. Immerse the bottle, which is covered with the penny, in the water and observe the dancing coin! (Make sure the coin covers the bottle mouth completely).

**What questions to ask:**

1. What was in the bottle before covering it with the coin?
2. What kind of water was in the beaker?
3. What was the moisture on the bottle opening necessary for?
4. Why did the penny or dime go up and down (vibrate)?
5. Would it also vibrate without moisture on the opening of the bottle?

**How to explain it:**

The bottle was filled with air before covering it with the coin. The moisture on the opening of the bottle functions as a **seal** between the inside and outside of the bottle. When the bottle is placed in the hot water, the air inside the bottle is heated and this causes the air inside the bottle to **expand**. The only way it can escape from the bottle is through the opening, and thus it has to lift the coin. The coin falls back, more air expands and lifts up the coin again. When this sequence of events happens quickly, a vibration of the dime is caused.

Without the moisture on the opening of the bottle, the coin does not seal off the air, so that the escaping air from inside the bottle could just seep under the coin out into the open without lifting the coin. The coin would thus not vibrate.

## 1.1.29. THE LIVE BALLOON

- What you need:**
1. A small balloon (one that has been inflated before).
  2. A large bottle with a narrow neck.
  3. A large beaker or container for hot water.

**How to do it:**

1. If another identical bottle is available put a few small things in this bottle; show the bottles to the students and ask them what is in the bottles (anticipated answer: 'nothing' in one of the bottles).
2. Place the small balloon over the mouth of the 'empty' bottle and let it hang limp against the side of the bottle (see Sketch A).
3. Fill the container with hot water (not steaming hot, if possible do not show students that it is hot water).
4. Immerse the bottle with the balloon on it in the hot water (the balloon will slowly fill with the expanding air) (see Sketch B).

Sketch A

Sketch B

**What questions to ask:**

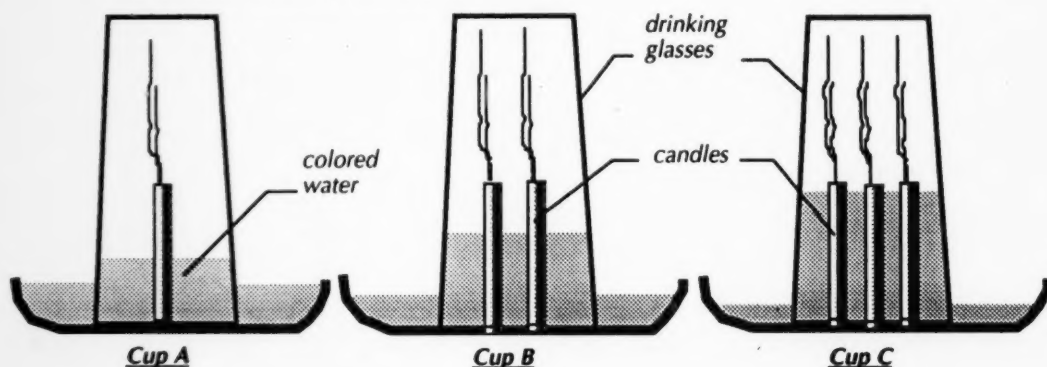
1. Before demonstrating: What is in the bottle?
2. Why did the balloon inflate itself?
3. What kind of water do you think was in the large container?
4. How can we deflate the balloon without taking it off the bottle?
5. What does air do when it is heated?
6. Is there more or less air in the warm bottle compared to the cold one?

**How to explain it:**

The bottle was filled with air at the moment that the balloon was put over it. The immersion of the bottle in the hot water **heated** the air inside the bottle, which made it **expand** and fill the balloon. The larger the bottle, the more air will expand, and the quicker the balloon will inflate. Taking the bottle out of the warm water and leaving it to stand on the table will cool it off and **contract** the air. This will deflate the balloon again. The amount of air is not changing, whether it is hot or cool, as no outside air was allowed in or out of the bottle. It is just the **volume** of air that is changing.

## 1.1.30. WHAT CAUSES THE WATER TO RISE (I) ?

- What you need:**
1. Three identical saucers or one large flat tray.
  2. Three identical glass cups.
  3. Six small birthday candles and matches.

**How to set it up:**

1. Attach one, two, and three candles to the center of each saucer or at different spots of the tray (in case of using a flat tray).
2. Fill each saucer with at least 3/4 cup of water.
3. Light all six candles and wait till they all burn evenly (same size flame).
4. Place the three cups at the same time over the candles on the saucer like illustrated (let a student help you).

**What questions to ask:**

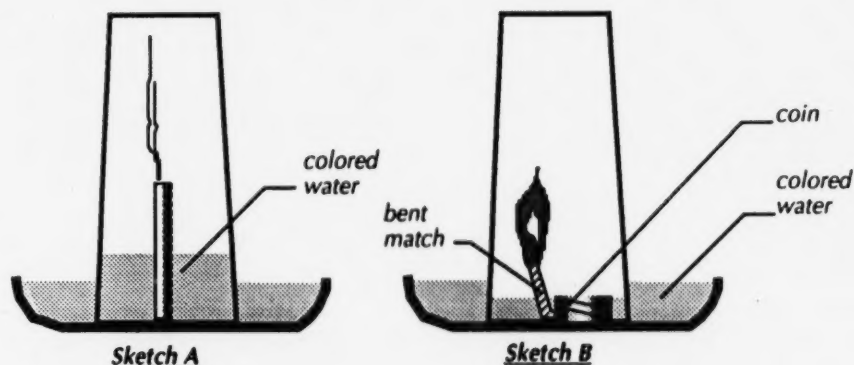
1. Under which cup does the water level rise highest?
2. Why did we take identical saucers, cups and candles?
3. Do we need to pour the same amount of water in the saucers?
4. Which variable is manipulated or changed in comparing A, B, and C?
5. Above which saucer did heat develop most?
6. Was the amount of air trapped under the cups the same for all three?
7. Why did the water level rise highest in case C?

**How to explain it:**

In all three cases the saucers, cups, and candles were identical. This meant that these variables did not influence the rising of the water level. The only variable that was changed or manipulated was the number of candles, and thus the **amount of heat**. This was the main factor causing the air under the cup to expand just before it hit the water, thus under cup C the **trapped air was the least** and thus exerting the **lowest pressure**. This is the reason why the water is pushed up the highest in cup C. Most students will think that the three candles will burn more oxygen, which is not the case. The use of oxygen for the burning process also helped in decreasing the pressure under the cups, but the amount of oxygen was the same for all three cases.

## 1.1.31. WHAT CAUSES THE WATER TO RISE ? (II)

- What you need:**
1. A small saucer and a glass cup.
  2. A birthday candle or wooden matches and a coin.

**How to do it:**

1. Attach the candle in the center of the saucer with a drop of melted wax (see Sketch A), or if no candle is available: break a short end of a couple of matches halfway and place them vertically on the saucer (using a coin as a weight to support them: see Sketch B).
2. Fill the saucer with about half a cup of water.
3. Light the candle or the two matches and cover it immediately with the inverted cup. Observe the water level

**What questions to ask:**

1. Why did the water level under the cup rise?
2. What does the candle need in order for it to burn?
3. Did the water level under the cup rise immediately after covering?
4. What did the heat of the flame do to the air under the cup?
5. Would the burning of two or three candles bring up the water level under the cup to the same height?
6. How would the size of the cup influence the rising of the water level? How can we set up experiments to test this?

**How to explain it:**

The burning of the candle needs oxygen and is therefore taking away all the oxygen under the cup. The flame is extinguished as soon as all the oxygen is used up. As the space under the cup does not contain any oxygen any more, it is **exerting less pressure** compared to the atmospheric air (carbondioxide and water vapor are produced, and the water vapor is condensing). The water is therefore pushed into the space under the cup. The major factor, however, contributing to the decrease of pressure inside the cup, is the fact that the **heat of the flame expanded the air** under the cup, just before it hit the water. At that moment air escaped from under the cup. After the flame extinguished, the remaining air cooled off and contracted and in so doing it sucked up the water.

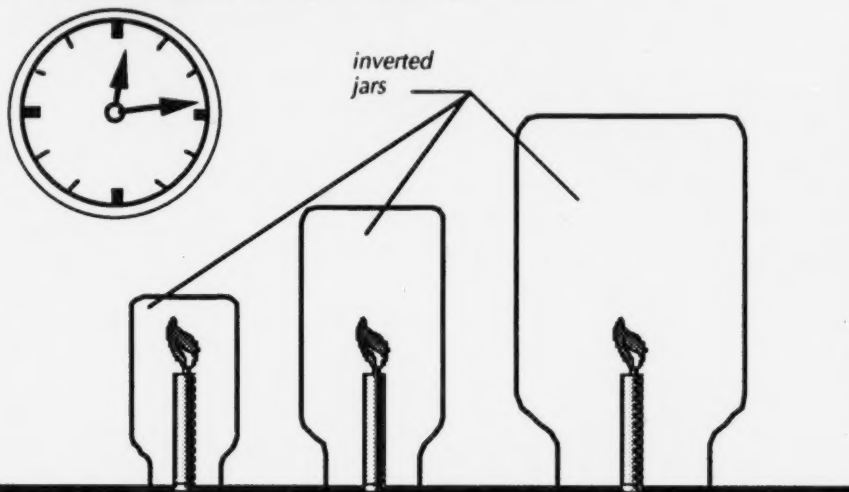


## 1.1.32. THE CANDLE UNDER THE JAR

- What you need:**
1. Three or more jars of different sizes.
  2. Three or more birthday candles (depending on number of jars).
  3. A large clock or watches for timing the burning candles.

**How to do it:**

1. Divide the class in small groups of three to six students.
2. Give each group one jar, one candle and matches.
3. Make sure that the students can see the large clock or that each group of students have a watch for timing.
4. Ask the groups to measure the burning time of the candle under the jar: Start timing as soon as the jar is put over the candle and stop timing when smoke evolves from the wick (repeat several times, make sure to replenish the air in the jar by shaking the jar, or by putting crumpled paper in and out the jar).
5. Compare size (volume) of jar (by measuring the volume of water that each of the jar holds) with the burning times (plot on graph).

**What questions to ask:**

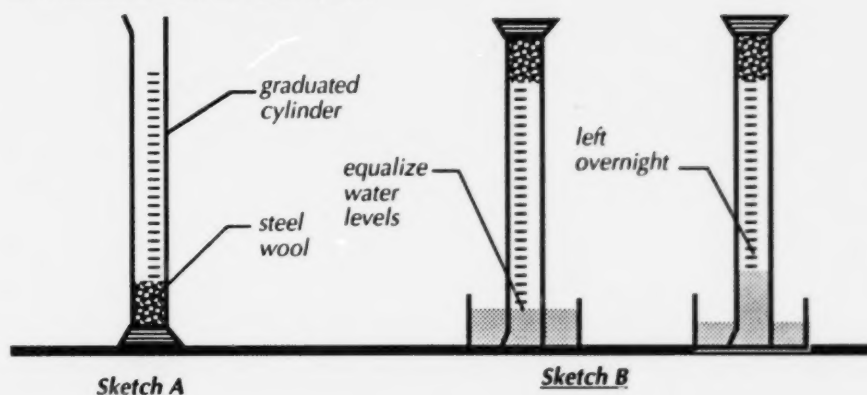
1. Why do we measure the burning time more than once?
2. What should we do to the gas in the jar before repeating the measuring of the burning time of the candle?
3. What do you think the burning time of the candle would be, if we did not replenish the air in the jar after the first reading?
4. Why did the candle stop burning under the jar?
5. How can we measure the volume of the jar?
6. What is the relationship between size or volume of the jar and the burning time of the candle?

**How to explain it:**

Air or actually oxygen in the air (about 20%) is needed to sustain the burning of the candle. After the first burning, the jar has no more oxygen. All the oxygen is replaced by carbon dioxide and water vapor, which latter can be seen condensing on the cold inside surface of the jar. Before doing a next timing of the burning candle, the air or oxygen in the jar has to be replenished. This can be done by pushing crumpled paper in and out of the jar several times or by shaking the jar. A **straight line relationship** exists between the volume of the jar and the burning time of the candle when the data are graphed, in other words the burning time changes in **direct proportion** to the size.

**1.1.33. THE WATER-ATTRACTING STEEL WOOL**

- What you need:**
1. Two graduated cylinders or two tall glasses.
  2. Two shallow dishes or trays.
  3. A small batten of steel wool.

**How to do it:**

1. Fill both shallow dishes with water.
2. Place the steel wool batten close to the bottom of one of the cylinders or tall glasses. (See Sketch A)
3. Wet this steel wool thoroughly by pouring some water in the cylinder.
4. Fill the cylinder one quarter full with water, cover it with a small paper card, place it upside down on the dish, and take the card out from under the inverted cylinder.
5. Adjust the water level in the cylinder evenly with the water level in the dish by letting an air bubble in the cylinder (holding it somewhat slanted) if the water level inside is too high (see Sketch B).
6. Repeat steps 4 and 5 with the other cylinder without the steel wool.
7. Place them side by side and leave them overnight. Observe the water level!

**What questions to ask:**

1. Why did the water level under the cylinder with the steel wool rise?
2. Did the steel wool change color? What happened to it?
3. What part of the volume in the cylinder did the water level rise?
4. What other chemical can we use in place of the steel wool?

**How to explain it:**

The steel wool in the cylinder reacted with the **oxygen** in the air forming iron rust ( $\text{Fe}_2\text{O}_3$ ). When all the oxygen under the cylinder has reacted with the iron, the water level should have risen about **one-fifth of the volume**, since 20% of the air consists of oxygen. Having taken away the oxygen under the cylinder, the pressure of the remaining air is decreased, forming a partial vacuum and thus sucking the water level higher up.

Magnesium ribbon or a chunk of white phosphorus (or anything that quickly rusts) may be used in place of the steel wool to bind the oxygen out of the air. The only challenge is that it has to be suspended in the bottom of the cylinder!

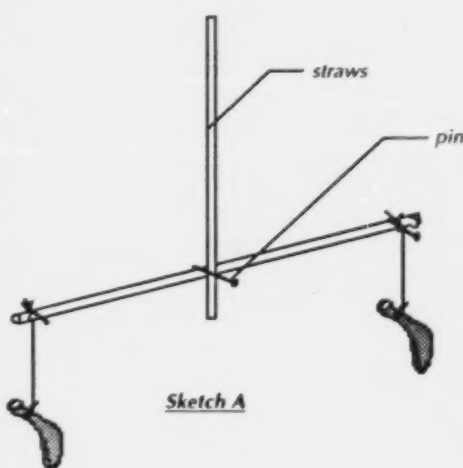
## 1.1.34. THE BALANCING BALLOONS

**What you need:** 1. Two drinking straws. 2. Three pins or needles & two pieces of thread.  
3. Two identical uninflated balloons.

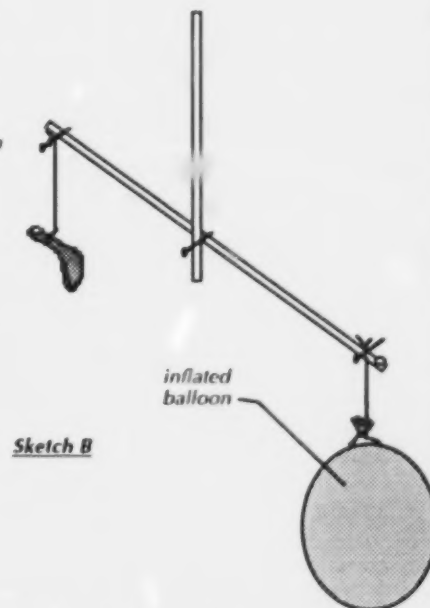
**How to do it:**

1. Tie a piece of thread to each of the two balloons and tie the threads to the two ends of one of the straws.

2. Balance this straw on your finger, push a pin through the straw where it is balancing and attach it to the other straw (see Sketch A).



Sketch A



Sketch B

3. Make sure that the straws are moving freely around the needle; balance the horizontal straw, then push a pin through at the spot where the threads are attached (to prevent them from sliding or this can also be done by taping).
4. Make sure that the two uninflated balloons are in perfect balance; then blow air in one of them and tie a knot in the mouth. The balance will tip down at the end of the inflated balloon! (See Sketch B).

**What questions to ask:**

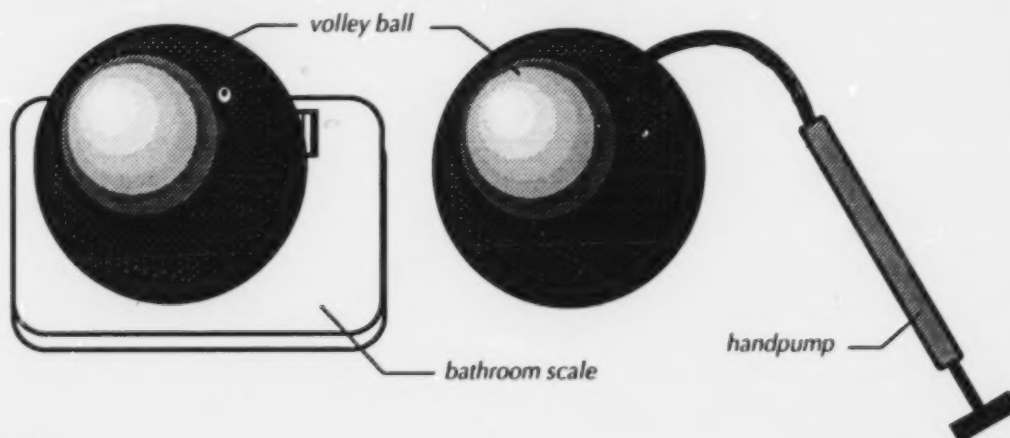
1. What is inside the uninflated balloons?
2. What kind of air was blown in one of the balloons?
3. What could happen if no pins were placed on the ends of the horizontal straw where the threads were attached?
4. What does the balance indicate after inflating one balloon?
5. What would you expect the balance would do if the other balloon was also inflated?
6. How else could we show that air has weight?

**How to explain it:**

The straw balance may be adjusted by moving the threads further or closer to the end of the straw. In order to keep these attached threads from sliding, we need the pins or the tapes. The air that was blown into one of the balloons was exhaled air, which contains some water vapor and carbon dioxide but, for our purposes, may be neglected. By inflating the other balloon, the balance should be brought in equilibrium again.

## 1.1.35. THE BALL THAT GAINS WEIGHT

- What you need:**
1. A basketball or volleyball (with a valve).
  2. A hand pump (to pump up the ball).
  3. A technical scale or balance (to weigh the ball).

**How to do it:**

1. Place a rather soft basketball or volleyball on the pan of the technical scale and read off the weight.
2. Connect the hand pump to the ball and pump ten strokes of air into the ball.
3. Disconnect the pump and read off the weight of the ball. How much did the ball gain in weight?
4. Repeat steps 2 and 3, and have students predict what the gain in weight would be after 5, 10, 15, 20, 25 strokes of the pump.

**What questions to ask:**

1. What made the ball gain in weight?
2. What can we say about the relationship between the number of pump strokes and the gain in weight of the ball?
3. How can we make the ball lose weight?
4. How much would a beachball gain in weight when pumped with 5, 10, or 15 strokes of the same hand pump?
5. Would an airtight bottle gain weight if air were pumped into it?

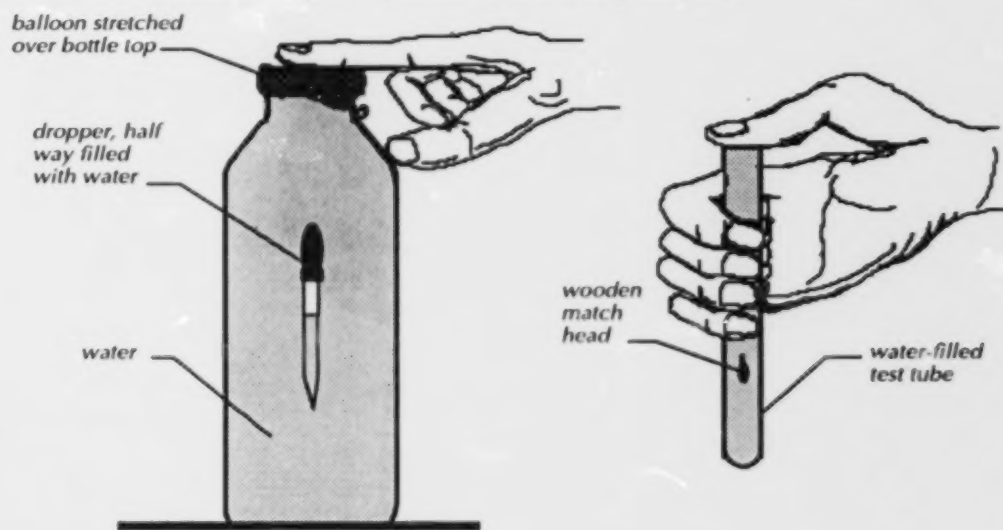
**How to explain it:**

This demonstration shows that **air has weight**. By adding air to the ball, it increases in weight. The same number of pump strokes should result in the same gain in weight. Half the number of pump strokes gives half the gain in weight. The number of pump strokes is therefore **directly proportional** to the increase in weight. If the data were plotted on a graph, a straight line relationship would be obtained between the number of pump strokes and the weight of the ball. Whether a ball or an air mattress or an airtight bottle is pumped, the increase in weight should be the same, provided that the same pump is being used and the same number of strokes is applied.



## 1.1.36. THE OBEDIENT DIVER

- What you need:**
1. A milk bottle or other jar, and a large beaker.
  2. A medium size test tube.
  3. A medicine dropper, wooden match, a large balloon.

**How to do it:**

1. Fill the beaker with water; fill the dropper half way with water and test it in the beaker: it should just float (more or less water in the dropper will make it sink or float).
2. Fill the bottle brimful with water and tie an uninflated balloon flat on the bottle opening (do this after you transferred the dropper from the beaker into the bottle).
3. Put your finger on the stretched balloon and control the sinking or floating of the dropper by putting pressure on it.
4. Ask the students to say "up" or "down" or "stop" and the dropper will respond to their command!
5. A broken off wooden match head in a water-filled test tube can be similarly controlled by pressure of the thumb (see Sketch B).

**What questions to ask:**

1. What made the dropper or the match head sink? Or float?
2. What did the water level inside the dropper do when it dove down?
3. Did the air inside the dropper increase or decrease in volume during the diving? During the floating?
4. Is water or air more compressible?

**How to explain it:**

By putting pressure on the stretched balloon with the finger, or with the thumb on the test tube, the air inside the dropper (or inside the wood fibers of the wood match) gets **compressed**, the water level rises and thus the whole dropper gets heavier and sinks. By releasing the pressure, the water is pushed out again, the dropper gets lighter and floats. This principle is applied in submarines, where water is pumped in to submerge or pumped out to surface. This demonstration is also suitable to initiate inquiry on **sinking and floating** or on **density**.

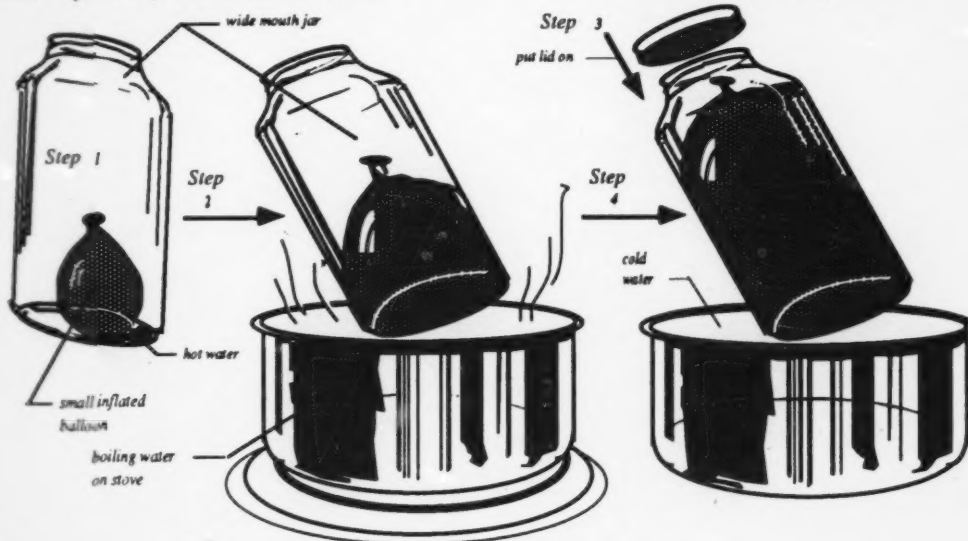


## 1.1.37

## THE BALLOON IN THE JAR

**What you need:** 1. A wide mouth jar (pickle jar) plus lid.  
3. Two deep steel pans, some table salt.

2. A round balloon.  
4. An electric or gas stove.

**How to do it:**

1. Inflate the balloon slightly by blowing (just large enough to slide it into the jar) and place a knot in it, then put the balloon into the jar plus a little water. (see Sketch Step 1)
2. Fill both steel pans with water and place one of them on the electric or gas stove pit, put one tablespoon of salt in the water and bring it to a boil.
3. Place the jar with the balloon in it in the boiling water (hold the jar with kitchen gloves) and wait till the water inside the jar is steaming hot. (see Sketch Step 2).
4. As soon as you see lots of water vapor coming out of the jar, screw the lid on tightly (Step 3).
5. Place the jar in cold water and roll it quickly around so that it is cooled off evenly on all sides (see Sketch Step 4). Observe the balloon inside the jar!

**What questions to ask:**

1. What was the purpose of the water inside the jar?
2. What was the purpose of the salt in the boiling water?
3. What made the balloon expand after putting the jar in the boiling water (Step 2)?
4. What made the balloon expand after putting the jar in the cold water (Step 4)?
5. Would the balloon keep expanding the same way if Step 3 (putting lid on) was left out?  
Why? Why not?
6. What would happen to the balloon if no water was added to the jar in the beginning?
7. In what ways can we reduce the size of the balloon after it is inflated in the jar?
8. What application in daily life can you mention that uses the same principle?

**How to explain it:**

This particular demonstration may be used to evaluate students' understanding of the concepts of **AIR EXERTS PRESSURE & AIR EXPANDS WHEN HEATED** (after having done Events 1.10 through 1.14 of ISI-2nd Ed). If the student can answer all the questions, you may be assured that he/she has a good grasp of the concepts mentioned.

The water in the jar was needed to be turned into steam when it was immersed into the hot water. This steam pushed almost all the air around the balloon out of the jar. Closing the lid immediately after steam has come out of the jar trapped the air out. Then when the jar was immersed in the cold water, the steam around the balloon **condensed** back into water leaving almost no pressure outside the balloon. This caused the balloon to inflate inside the jar! Would this same event happen if the balloon was not partially inflated before placing in the jar?

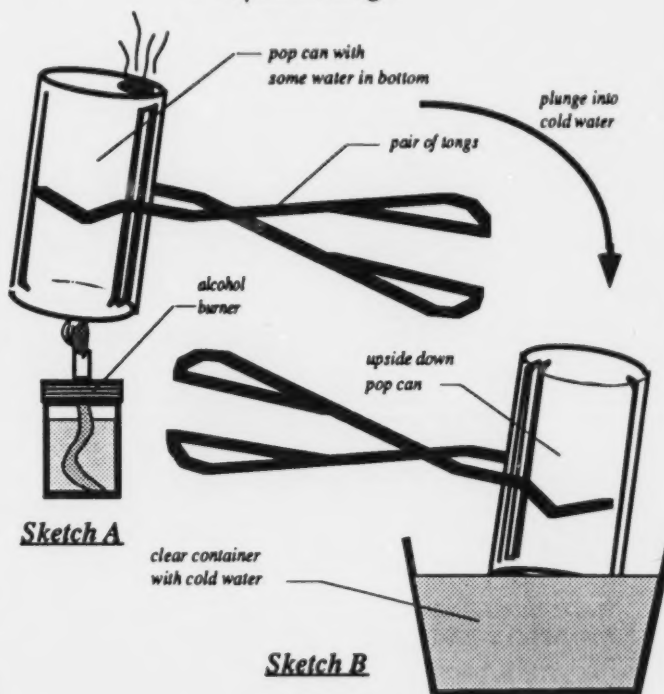
## 1.38 THE CRUSHING POP CAN

**What you need:** 1. An empty soda pop can.  
1. An alcohol or Bunsen burner.

2. A clear bucket of cold water.  
4. A pair of tongs.

**How to do it:**

1. Put a small amount of water in the soda pop can (enough to cover the bottom of it).
2. Hold the can with the pair of tongs and hold it in the flame of the burner (see Sketch A).
3. Keep holding the can above the flame until lots of vapor/steam is seen coming out of the can.
4. Keep the clear container of cold water close by the burner, and plunge the pop can upside down in the bucket of water (see Sketch B). Observe!!

**What questions to ask:**

1. What did the pop can suddenly do after turning it upside down in the water?
2. What was the function of the water inside the pop can in the beginning?
3. What did the water do when we heated the can above the flame?
4. Why did we have to wait till lots of steam was seen before plunging the can in the water?
5. What would happen if we did not wait till the water was boiling vigorously?
6. What would happen if we plunged the pop can right side up into the water?
7. What is the main cause for the pop can to be crushed?
8. Could we have done this demonstration on the surface of the moon? What things would go differently on the surface of the moon?

**How to explain it:** This demonstration is equivalent to THE COLLAPSING CAN (earlier in this chapter). It can be used either for a reinforcing student activity or an assessment of student understanding of the concept of **air exerting pressure**.

The main cause for the pop can to collapse is that the air around the can **exerted pressure**, and inside the can there was very little pressure left, since the water vapor pushed almost all of the air out (this is why we had to wait for seeing a lot of vapor/steam escaping from the can). At the moment that the can was plunged upside down in the cold water, the water vapor suddenly **condensed** and left a **partial vacuum** inside. Since the can was plunged in the water upside down, the opening was closed off by the water. Some water was pushed into the can, but this cooled the can even more down, which caused the water vapor to condense even quicker.

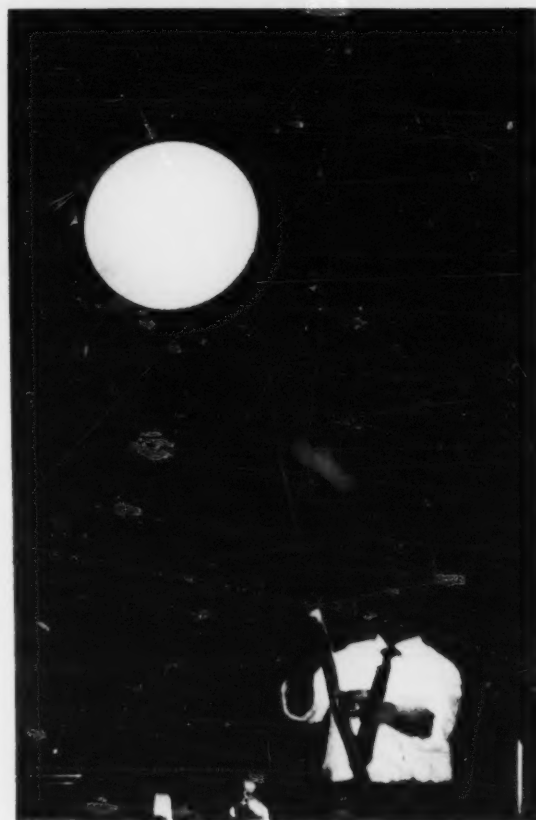
If the can was plunged into the cold water right side up, probably nothing spectacular would have happened. The cooling would have condensed the water vapor, leaving a smaller pressure inside the can, but then the air would have a way to come in and nothing would have happened.

If we had a way of closing off the opening before plunging it into the water, it would have crushed the same way. On the surface of the moon: 1. the flame would not be sustained, 2. if we used electric heating, the water would boil at very low temperatures, 3. When plunging the can upside down in the water, nothing would have happened.

USE **SIMPLE MATERIALS**

TO SHOW **PROFOUND**

**SCIENCE PRINCIPLES**



Showing Bernoulli's Principle being used in modern technology.

# CHAPTER 2

## WHAT CAN FLOWING AIR DO ?

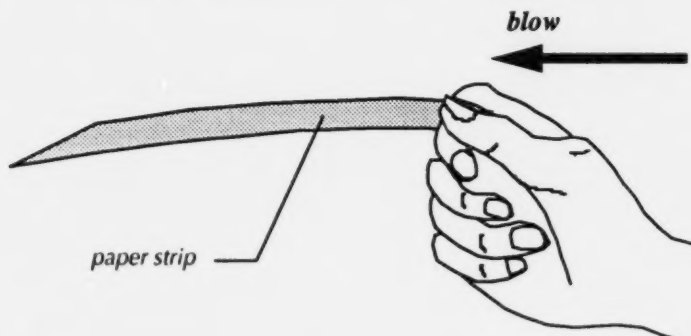
### **OBJECTIVES**

After dealing with and studying the concepts in this chapter, the students should be able to:

- a. Recognize the correct explanation of an observed event based on the Principle of Bernoulli;
- b. Distinguish true from false statements concerning events applying the Principle of Bernoulli;
- c. Distinguish between air flow along a surface and air flow against a surface (wind energy);
- d. Identify the correct explanation of an event in daily life applying the Principle of Bernoulli.

## 1.2.01. THE LIFTING PAPER

**What you need:** 1. Strips of paper of about 15 x 3 cm (for each of the students).

**How to do it:**

1. Hand out a strip of paper to each of the students.
2. Have them make a fold at one end of the paper strip.
3. Holding the paper strip by the folded end, let them blow against the underside of the paper: what do you observe?
4. Now hold the strip near the chin and blow over it (let the students try and predict what will happen to the strip).

**What questions to ask:**

1. What did you observe in the first instance? (Blowing under it).
2. What did you observe in the second case? (Blowing over it).
3. What do you know about the properties of stationary air?
4. What is different about the air on top of the paper compared to that underneath the paper, when we blow over it?
5. What effect does the moving air have on the gravity that is working on the strip of paper?

**How to explain it:**

Stationary air exerts pressure in all directions. When we blow over the top of the paper strip, we are creating a faster moving flow of air above the strip. **The faster the flow of a fluid** (in this case the air), **the lower the pressure it exerts** (Bernoulli's Principle):

$$P + \frac{K.E.}{V} = \text{Constant, where } P = \text{Pressure, K.E.} = \text{Kinetic Energy and } V = \text{Volume}$$

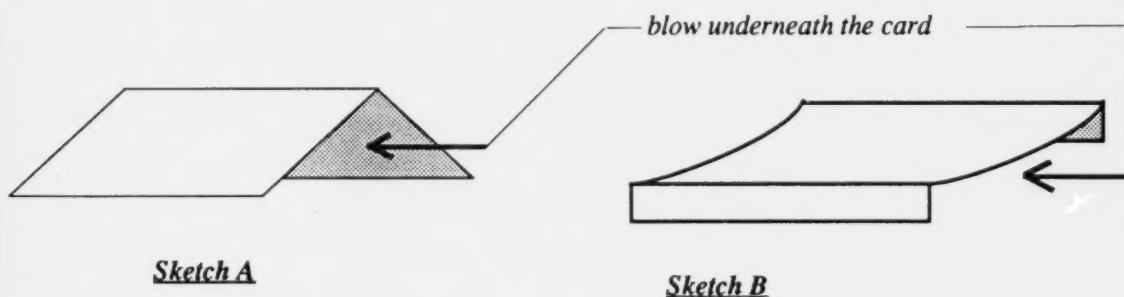
This last ratio can be equated with the velocity of the moving fluid. The effect of the moving air above the strip of paper is, that it reduces the pressure above the strip. Thus the higher pressure under the strip pushes the paper up into the lower pressure region.



## 1.2.02.

## THE STUBBORN PAPER CARD

**What you need:** 1. Paper cards (3" x 5") for each of the students.

**How to do it:**

1. Distribute the 3 x 5 cards to each of the students.
2. Fold the cards either in the center (Sketch A) or fold them at each end about 1 cm from the edge (see Sketch B).
3. Place the folded card on the table or desk and try to blow the card off the table by blowing underneath it (with a straw). What do you observe?

**What questions to ask:**

1. What did you observe when blowing underneath the paper ?
2. What properties does stationary air have?
3. What is different about the air underneath the paper compared to that above the paper , when blowing underneath it?
4. Why do you think the paper did not fly off the table?
5. What is different about flowing air compared to stationary air?

**How to explain it:**

This activity can be a follow-up to 'The Lifting Paper ' in dealing with Bernoulli's Principle. Among other properties, stationary air exerts pressure. Flowing air **exerts less pressure** as compared to stationary air. The faster the flow, the lower the pressure it exerts. By blowing underneath the card, we actually created less pressure underneath the paper , so that the pressure above the paper became larger than below the paper, and this is why the card got pressed down against the table.

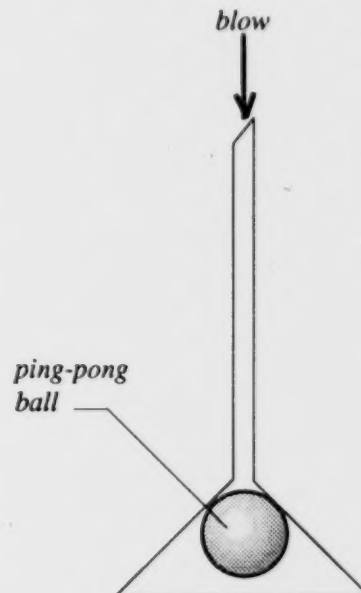
In terms of moving molecules, we can see that by blowing underneath the card, the air molecules are pushed away from under the card. It is as if a partial vacuum is created at the spot where one is blowing. The air molecules that surround the card, those on the side as well as those above the air stream, are sucked towards this spot. In rushing to replace the molecules that were blown away, these air molecules push on the upper side of the card, thus bending it down towards the table.

## 1.2.03. THE FUNNEL AND THE BALL

- What you need:**
1. One long-stem funnel (glass or plastic).
  2. One ping-pong ball.

**How to do it:**

1. Place the funnel and the ball next to each other on the table.
2. Ask: "How can I pick up the ball with the funnel without sucking through it? I may not touch the ball."
3. Pick up the funnel by the stem, place it over the ball and blow through the stem, lift the funnel while blowing.
4. Hold one hand under the funnel and stop blowing (ball drops in hand).
5. Place the ball in the funnel and have a student try to blow it out of the funnel (he/she will not succeed).

**What questions to ask.**

1. How did we pick up the ball with the funnel without sucking through it?
2. What happened when we stopped blowing?
3. Is it possible to blow the ball out of the funnel?
4. Where is the air moving fastest when we blow through the funnel?
5. What is flowing air creating that stationary air doesn't?
6. What is the difference about the inside compared to the outside of the funnel when blowing through it?

**How to explain it:**

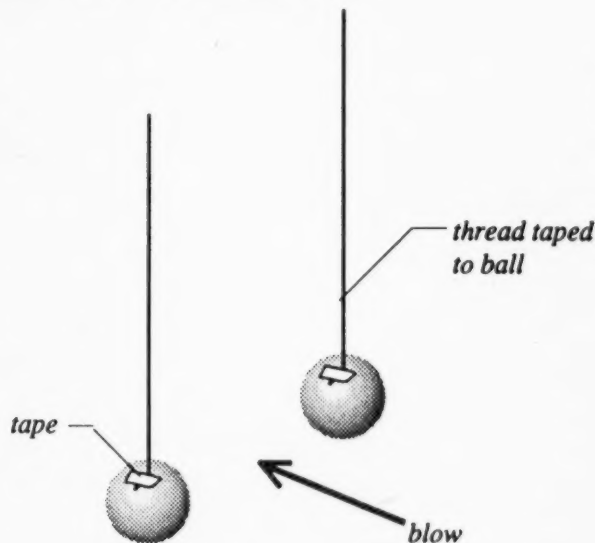
The ball can be picked up from the table with the funnel by blowing through it. By blowing through the funnel, we create a lower pressure inside the funnel, especially at the spot where the stem is attached to the conical shape of the funnel. Here the fastest flow of air occurs, because the air molecules have suddenly more space to move about. **The faster the flow of air, the lower the pressure.** This is why the ball is sucked into the funnel by blowing, and for the same reason it is not possible to blow the ball out of the funnel. The harder we blow through the funnel, the lower the pressure gets in the mouth of the funnel.

**1.2.04. THE ATTRACTING SPHERES**

- What you need:**
1. Two plastic spheres (tennis balls or apples will work).
  2. Two lengths of thread (about 40 cm) & adhesive tape.

**How to do it:**

1. Tape the two pieces of thread to the two spheres.
2. Hang the two spheres about 3 cm/1 inch apart from a horizontal support, or let someone hold them (you can also hold them up yourself).
3. Ask: "What would you expect the balls to do when I blow in between them?" (Anticipated answer: fly apart).
4. Blow in between the two hanging spheres and observe the movement of the two spheres (hard plastic spheres will click together). (Empty soda pop cans may be used instead of spheres).



**What questions to ask:**

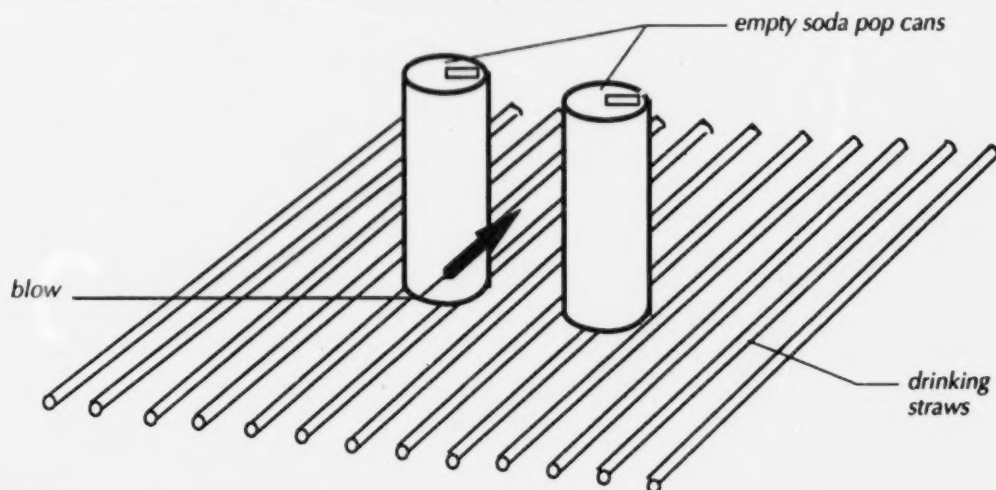
1. What do you observe when blowing straight against one ball?
2. What did you expect the two spheres would do when blowing between them?
3. What did you observe the two spheres were doing when blowing in between?
4. What did we create between the balls by making the air flow?
5. What is different about the air between the two spheres as compared to the surrounding air?

**How to explain it:**

When blowing head on against one sphere, we observe that the sphere moves away from the source of the air flow. This is because the air molecules bump directly against the surface of the sphere, the kinetic energy is transferred to the sphere and it is thus pushed away. When blowing in between the two spheres, we are actually **pushing away the air molecules** and thus creating a **lower pressure**. The stationary air surrounding the two spheres on the outside exerts a higher pressure and pushes them against each other. Applications of Bernoulli's Principle with spheres are encountered in playing tennis or baseball. A top spin in tennis creates a stronger and faster air flow under the ball and curves the path down (and the ball stays in court). A spin throw of a baseball curves the ball path in the direction of the spin.

## 1.2. 05 . THE CLANGING SODA POP CANS

- What you need:**
1. Two empty soda pop cans.
  2. About two dozen straight drinking straws.

**How to do it:**

1. Spread the straws parallel to each other on the table and leave about 1/2 to 1 cm (1/4 to 1/2 inch) gap in between them.
2. Place the two cans upright about 2 cm (1 inch) from each other on the straws and show the students that they can easily move closer or further apart.
3. Ask: "What will happen to the cans if I blow in between them?"
4. Now spread the two cans about 5 cm (2 inches) apart. Ask: "Do I have to blow softer or harder to get the two cans clanging?" Answer: Blow harder!
5. Now place the cans about 20 cm (a foot and a half) apart. Ask: "Can I still get the two cans clanging against each other?" Take a deep breath and blow a constant stream of air on the right side of the left can and move your head towards the right, while constantly blowing (the left can will move to the right and the cans will clang!).

**What questions to ask:**

1. What made the cans move towards each other?
2. How far apart could the cans be placed and still be drawn together?
3. What does the flowing air create in between the cans?
4. Was a stronger flow of air necessary to bring the cans that were 20 cm apart together?

**How to explain it:**

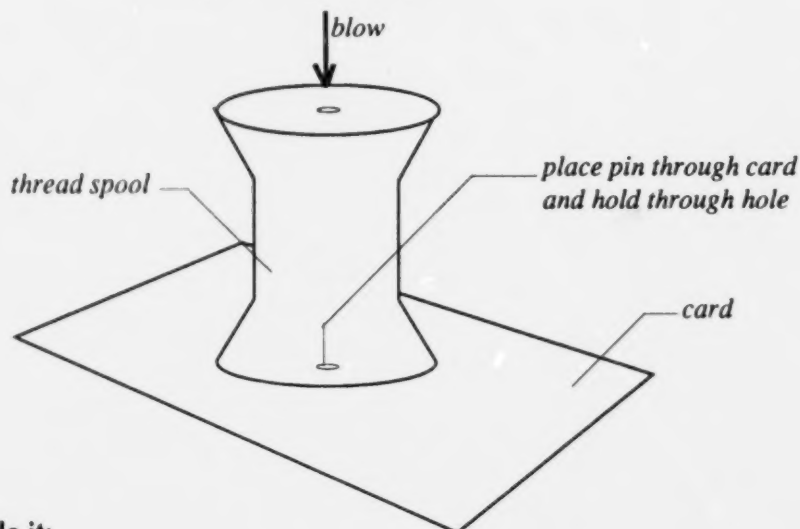
Blowing in between the cans created a flow of air and thus a **lower pressure** compared to the stationary air on the other side of the cans. It is this lower pressure that drew them together. Theoretically, the cans could be placed an infinite distance away from each other and still be drawn together, as long as a constant flow of air on one side of one pop-can moves along with it, to move it to the other pop-can. Indeed, **the faster the flow of air, the lower the pressure it exerts**. But for the cans that were placed 20 cm apart, only a constant flow that could move with the can, was necessary.



## 1.2.06.

## THE FLOATING CARD

- What you need:**
1. A paper card (3 x 5").
  2. A thread spool and a head pin.

**How to do it:**

1. Hold the card up vertically close to the mouth and blow against it and let go. What did the card do?
2. Now push the pin through the center of the card.
3. Hold the card against the spool with the pin sticking in the hole of the spool. Ask: "What would you expect the card to do when I blow through the hole of the spool?" (Anticipated answer: 'blow away' or 'the card will fly right across the room').
4. Now blow through the hole of the spool and let go of the card (card should stick against the spool) Hold the spool vertically and blow down, only when you stop blowing will the card fall off the spool.

**What questions to ask:**

1. What did you observe when blowing against the card without the spool?
2. What did you observe when blowing through the hole of the spool against the card?
3. Where was the faster flow of air created?
4. What is different about the air above the card as compared to the air under the card (while blowing through the spool hole)?
5. What is keeping the card against the spool?

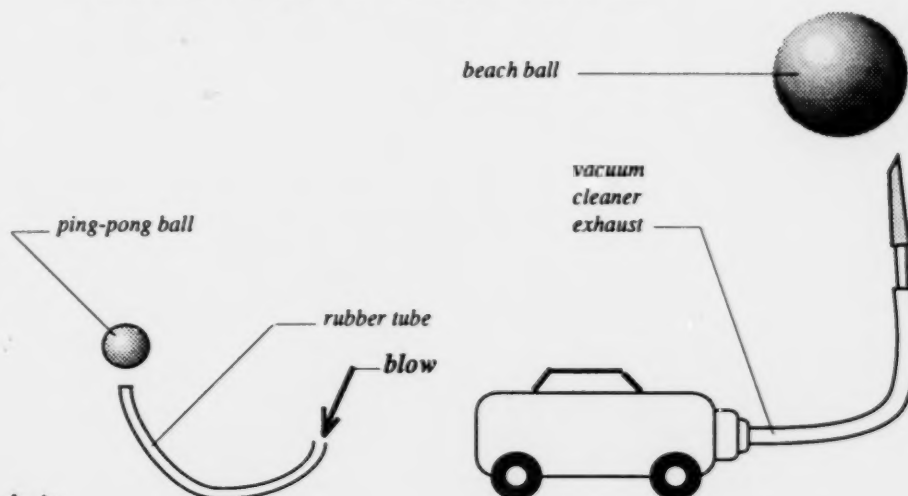
**How to explain it:**

By blowing in the hole of the spool, we are creating a faster flow of air above the card, thus creating a **partial vacuum** at this spot: between the card and the spool. The relatively slower moving air, which is surrounding the card, exerts a higher pressure compared to the air between the card and the spool. This makes the card stay close to the spool. As soon as we stop blowing through the spool, the card drops, because the pressure above and below the card is equalized.



## 1.2.07. THE FLOATING BALL

- What you need:**
1. A ping-pong ball or a beach ball.
  2. A 25 cm length of rubber tubing or a bendable drinking straw.
  3. A small hair dryer.
  4. A vacuum cleaner (when using the beach ball).

**How to do it:**

1. Take the rubber tubing with each hand on one end of the tube or take the straw and bend it.
2. Place the ping-pong ball on one end of the tubing and blow through the other end, and balance the ball in the air flow.
3. When using a beach ball, you will need a vacuum cleaner. Detach the vacuum cleaner hose and attach it to the exhaust end, so that it blows through it rather than producing a suction.
4. Blow air into the beach ball and let the ball hang in the air stream that the vacuum hose is producing.
5. When a small hair dryer is available, take a round blown-up balloon or a ping-pong ball and hang it in the air stream. (Tie a thin thread to the balloon, hold the thread with one hand, leave it on the table-top, blow air against it with the other hand, lift the air stream and you can simulate the take off and landing of an airplane!).

**What questions to ask:**

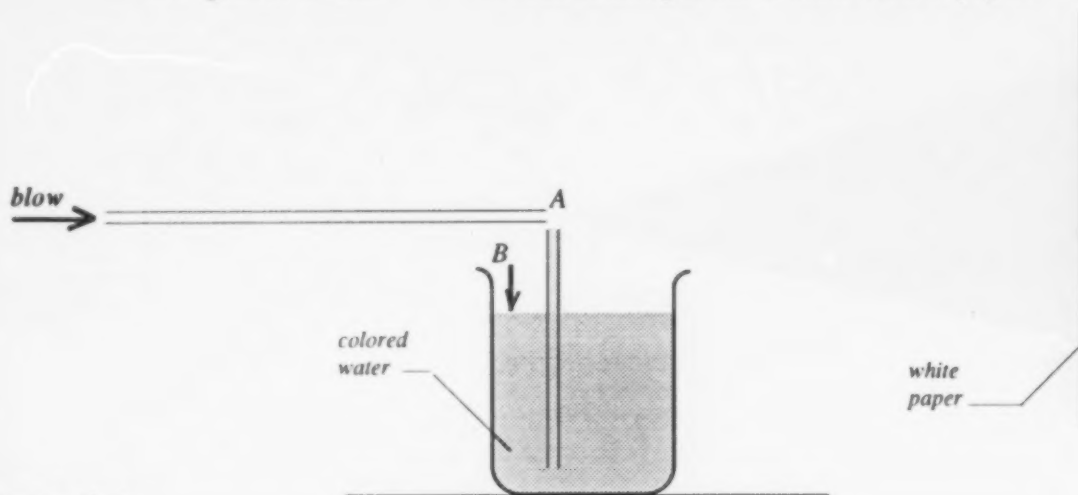
1. Will we be able to do the same thing with other round objects?
2. What property of the round object is critical for it to stay afloat?
3. What does the blowing do to the movement of the air molecules?
4. How does the pressure of flowing air compare to that of stationary air?
5. Why does the ball stay afloat in the air stream?

**How to explain it:**

By blowing through the straw or by using the hair blower or the exhaust of the vacuum cleaner, we are creating an air flow. This air flow causes the existence of a lower pressure area compared to the surrounding air, which is stationary or not moving as fast. **Bernoulli's Principle** states that: **the faster the flow of air, the lower the pressure.** This means that at the place of exhaust (end of the straw or hose), a cone of lower pressure is created. All the surrounding air is exerting a higher pressure and thus the ball is kept in the lower pressure area, which is the cone above the exhaust.

1.2.08. **LIFT WATER BY BLOWING**

**What you need:** 1. Two drinking straws (transparent ones).  
 2. A glass or beaker. 3. Food coloring or ink & white sheet of paper.

**How to do it:**

1. Fill the beaker about 3/4 full with water and add a few drops of food coloring or ink to it, and stir.
2. Cut one of the straws in half and dip this short straw vertically in the colored water (hold this with the left hand).
3. Place the long straw with the right hand horizontally against the top opening of the vertical straw (see Sketch above).
4. Ask a student to hold a white sheet of paper on the other side of the equipment set-up.
5. Blow through the horizontal straw until the colored water is sprayed against the paper. (The horizontal straw might need some adjusting up or down against the vertical one before the water comes out - make sure that the angle between the two straws is 90 degrees).
6. Have a contest: 'Who can lift the tallest water column?'

**What questions to ask:**

1. What do you create by blowing the air with the straw?
2. How does the pressure at the meeting place of the two straws compare with that on the water surface of the beaker?
3. What is it that lifts the water in the vertical straw?
4. Would this also work with a longer vertical straw?
5. Where do we find this principle applied?

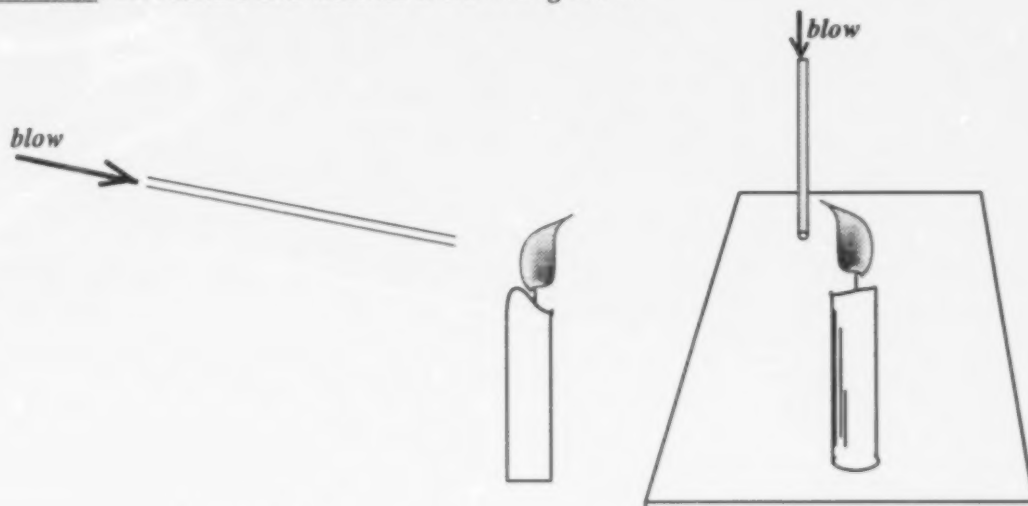
**How to explain it:**

By blowing through the horizontal straw, we are creating a flow of air and **the faster the flow of air, the lower the pressure** (Bernoulli's Principle: see Event 2.1.). Thus the pressure at A is smaller than at B (see Sketch), and this pressure difference makes the water move upwards in the vertical straw. The longer the vertical straw, the harder we have to blow to create a larger pressure difference. Applications of this principle are found in spray guns for painting, in spray bottles of perfume - perfume atomizers, insecticide spray pumps, etc.

## 1.2.09.

## THE MYSTERIOUSLY MOVING FLAME

What you need: 1. A candle and matches & a drinking straw.

How to do it:

1. Light the candle and attach it to a card and place it on the table.
2. Blow through the straw directly against the flame from a distance of about two feet (half a meter), such that the students get the side view of it (Sketch A).
3. Now hold the straw to the side of the flame, blowing straight into the face of the observer, ask: "Where will the flame move to when I blow? Towards or away from the straw?" (Sketch B).
4. By moving the straw radially in a semi-circle and repeating point 3, make sure that every student has a good view of the moving flame.

What questions to ask:

1. Why did the flame move away from the straw in set-up A?
2. Why did the flame move towards the straw in set-up B?
3. What variable is decreased by increasing the flow of air?
4. What principle is this phenomenon based on?
5. Where do we find this principle applied in daily life?

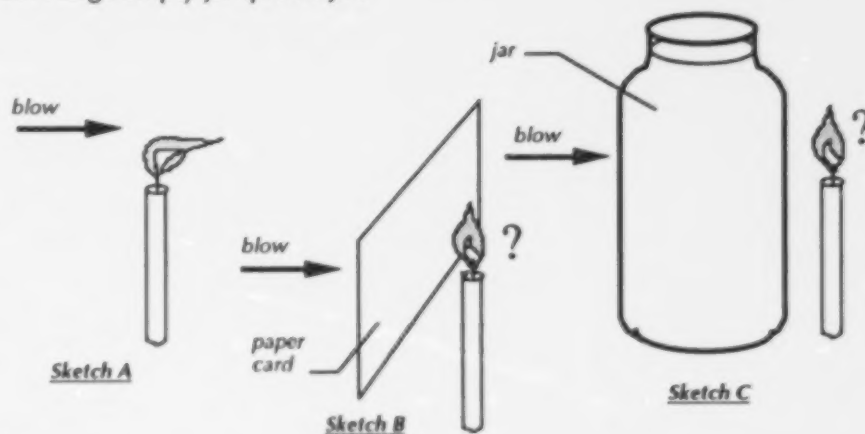
How to explain it:

This event is again based on Bernoulli's Principle, which states that **the faster the fluid flows, the lower the pressure the fluid exerts**. In this case the fluid is air. The air on the straw side of the flame is flowing and thus compared to the air on the other side of the flame, which is stationary, it exerts a lower pressure. For this reason the flame bends towards the straw. When blowing straight against the flame, this latter gets immediately into the air stream and can be compared to a flag waving in the wind.

Applications of Bernoulli's Principle are encountered in our daily life in the lift that airplanes are getting when flying; the shape of the wings makes the air flow faster over the wing than under it (Event 2.11.). Other applications are found in throwing curved balls in baseball pitching and in using top spins in playing tennis. The carburetor in a car applies this principle constantly, where the gasoline is drawn in by a flow of air and the mixture is then drawn into the cylinders for combustion.

## 1.2.10. WHICH WAY WILL THE FLAME FLICKER ?

**What you need:** 1. A candle and matches. 2. A paper card (3 x 5" or 10 x 15 cm).  
3. A large empty jar (pickle jar)

**How to do it:**

1. Light the candle and attach it to a card and place this on the table.
2. Stand to the side of the candle and ask which way will the candle flame flicker when I blow from this side?" (Your side).
3. Blow slowly against the flame: the flame moves away from you (Sketch A).
4. Place a card vertically between you and the candle, and ask again: 'which way will the candle flame flicker when I blow?'
5. Blow hard against the card and let students observe the flame. (B)
6. Place the empty jar between you and the burning candle. Repeat the question and blow hard against the jar (see Sketch C) - you can blow the flame out!

**What questions to ask:**

1. What does flowing air against the card create?
2. From your observation of the candle flame movement with the card, on which side of the candle was the air pressure lower?
3. Why did the candle flame not behave in the same way with the jar as with the card when blown against?
4. What would happen with the candle flame behind the jar, if we blew really hard against the jar?
5. Why are fast moving vehicles almost never squared off at the rear?

**How to explain it:**

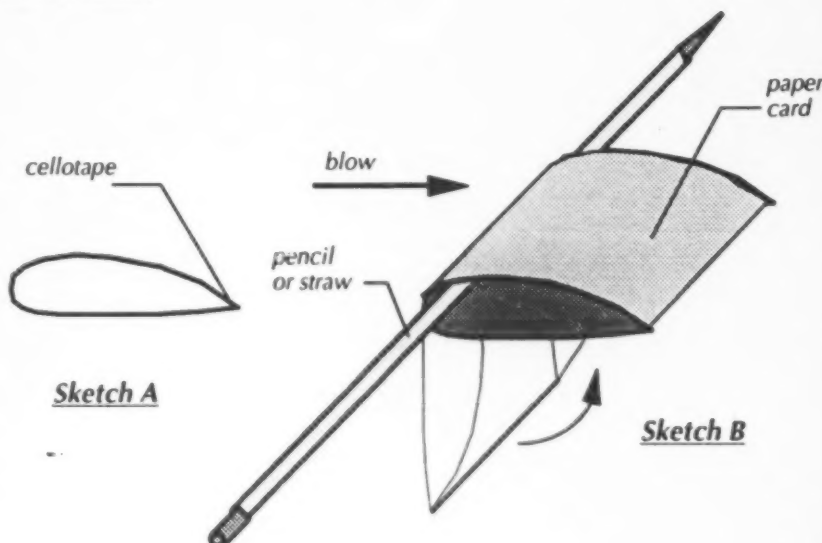
Blowing air against the card creates a **turbulence** of air behind the card and thus a lower pressure. The flame is drawn to the spot of **lower air pressure** and therefore is bent towards the card. When blowing against the jar, the air can smoothly flow around the jar and when the blowing occurs hard enough, the flame can easily be extinguished. This is an example of a streamlined fast moving object. Vehicles that are squared off at the rear have problems with turbulence, which is creating a pocket of low pressure in the rear of the vehicle, forming a drag. Large trucks on the highway have a turbulent flow of air behind them, which can be felt when driving in a car and when being passed by the truck.

## 1.2.11. THE PAPER WING

**What you need:** 1. A piece of paper or paper card and cellotape.  
2. A round pencil or straw.

**How to do it:**

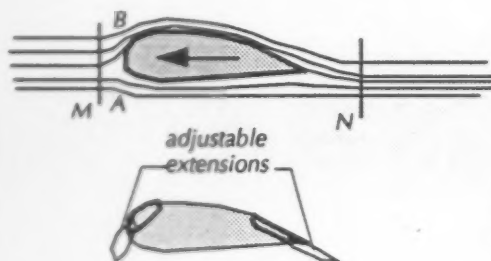
1. Cut a piece of paper of about 5 x 15 cm and bend it in the shape of an air-plane wing (Sketch A) and tape the ends together.
2. Put a pencil or straw through the wide end of the wing and let the paper wing hang vertically down (see Sketch B).
3. Blow over the paper wing (it should move up horizontally).

**What questions to ask:**

1. Why does the paper wing move up when blown over it?
2. What would happen if you blew under the paper wing?
3. What happens if you blow over the wing, but invert it (with the curved side facing down)?
4. What gives airplanes the air lift?
5. What do airplanes do with their wings when they take off or land?

**How to explain it:**

Bernoulli's Principle is underlying and causing the airlift that the airplane wing provides. The wing is built in such a way that the air over it flows faster than the air under it when going through the air. It has a greater curvature on the top compared to the bottom side.



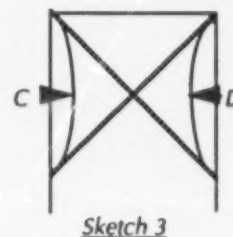
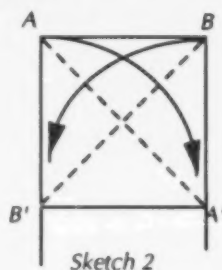
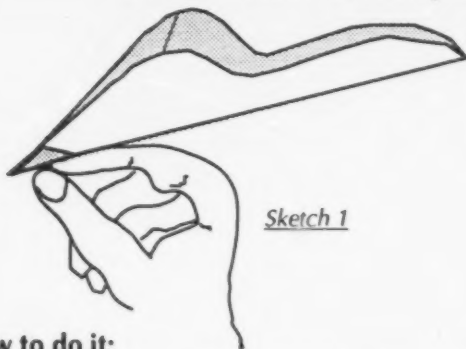
When we consider an air molecule A on the top side and molecule B below the wing, and they have to run from point M to N, it can be seen that A has to run faster than B, because of its longer path.

The wings of an airplane are provided with adjustable flaps that can be extended or retracted. When extended, it increases the curvature of the wing on the upper side and provides a greater lift for starting and landing.

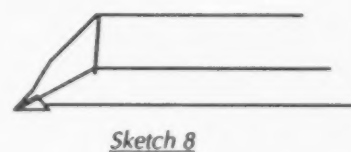


## 1.2.12. THE PAPER AIRPLANE CONTEST

- What you need:**
1. Onion skin or tracing paper.
  2. Small scissors (for each pair of students).

**How to do it:**

1. Take a rectangular shape of thin paper (10 x 20 cm) and make two creases AA' and BB' by bringing over B to B' and A to A' (Sketch 2).
2. Lift the middle of AB' = C and the middle of BA' = D up (Sketch 3) and push points A and B down over B' and A' (Sketch 4).
3. Now lift point B up and bring it over to point M. Do the same with flap A, and crease the fold (Sketch 5).
4. Pinch flap F and fold over towards the front (point M), and do the same with flap E (Sketch 6).
5. Fold point M towards the back side of the paper (Sketch 7) and fold along the axis of symmetry to obtain Sketch 8.
6. Cut the plane in any shape you want (experiment with it) and bend wings up or down, and tail elevators up or down.
7. Fly the planes: the longest one to stay up wins (Sketch 1).

**What questions to ask:**

1. What makes the paper plane fly farthest?
2. What makes the paper plane turn to the left or right?
3. Would thinner or thicker paper make the plane fly farther or longer?

**How to explain it:**

When the elevators are angled up, the flowing air pushes it down and the plane climbs. The rudder works just like that of a boat. Turning it to the right moves the tail to the left and the whole plane turns to the right. Ailerons are used to roll the plane and the flaps to increase the curvature of the wings and increase the lift.



## 1.2.13

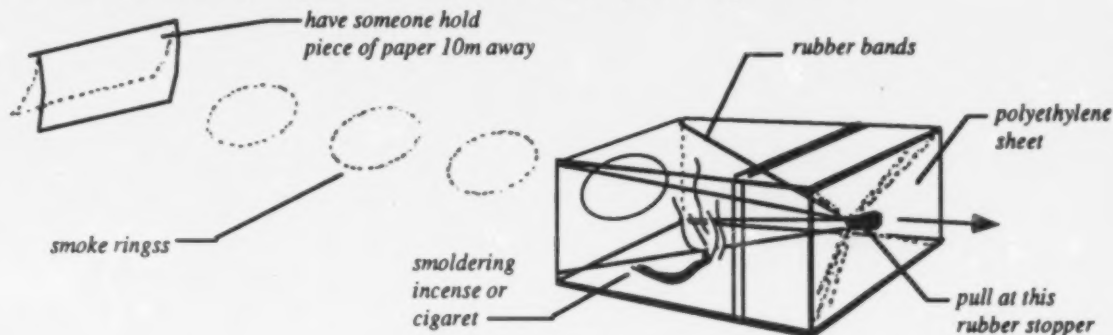
## MAKE AN AIR BULLET SHOOTER

**What you need:** 1. A medium sized cardboard box.

2. A heavy polyethylene sheet (to cover one end of the box).

3. Four long heavy rubber bands, a rubber stopper.

4. An incense stick, a cigarette or any other smoke producing material.

**How to do it:**

1. Cut a circular hole of about 15 cm diameter in the bottom of the box, and flip the flaps of the open side inwards.
2. Staple the long rubber bands to the four corners of the side with the hole, and staple the other end of the bands to the rubber stopper.
3. Cover the open end of the box rather loosely with the polyethylene sheet and tape the edge of the sheet tightly against the box.
4. Push the rubber stopper against the center of the sheet, wrap the sheet around the stopper, and tie it with a small thick rubber band.
5. Now the air shooter is ready. Have someone hold a paper or cloth sheet about 10 meters away and shoot air bullets at the sheet by holding the box, aiming the circular hole at the sheet, pulling the rubber stopper and release it suddenly (see Sketch above).
6. The air shooter can also be used to produce smoke rings. Tape the two small Petri dishes next to each other inside the box, place a few drops of concentrated ammonia in one and a few drops of concentrated HCl in the other dish, and shoot smoke rings!

**What questions to ask:**

1. What makes it possible to blow at the paper sheet from 10 m away?
2. Would a square or triangular opening have the same effect?
3. What shape would the "air bullet" have?
4. What did the smoke consist of?

**How to explain it:**

The circular opening in the box made it possible for the air to form ring shaped "bullets" that can move through the stationary air much faster and farther. Other shapes of the opening in the box would hamper this natural travel of fluids. The smoke was formed by the gases or vapors of ammonia and hydrochloric acid:  $\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$ , forming ammonium chloride, which is a solid (smoke consists of finely divided solid particles in a gas).

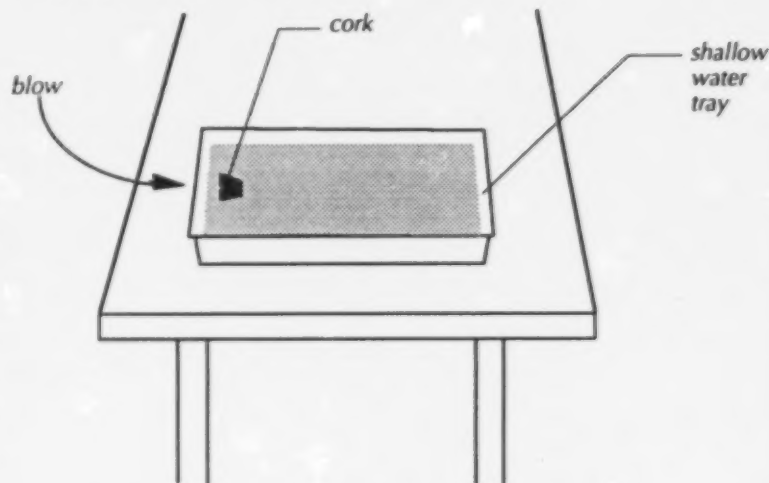
Fill the air shooter box with air freshener mist or perfume, and shoot perfume "bullets" to the people in the audience!

**1.2.14. THE CORK RACE**

- What you need:**
1. Different size corks (one per pair of students).
  2. A shallow tray (one per pair of students).

**How to do it:**

1. Distribute one cork and one tray to each pair of students.
2. Let the students fill the tray with water and float the cork on the water (making sure that the cork does not drag on the bottom of the tray; add more water if this is the case).
3. Position the students facing each other with the tray in between them (the cork may not be touched during the race).
4. On the count of three, one student blows the cork across the tray, and the other student indicates (raises hand) as soon as the cork has crossed over (reached the other side). Students take turns blowing. The student with the shortest crossing time wins.



**What questions to ask:**

1. What made the cork move over the water?
2. Which cork moved faster: the smaller or the larger one?
3. What are other factors that influence the speed of the moving cork?
4. What type of energy was used to move the cork?
5. Which side of the cork, when blown against, results in a faster speed?

**How to explain it:**

The flowing air blowing against the cork consists of a stream of moving air molecules possessing **kinetic energy**. This energy is imparted upon the cork resulting in its movement. The speed of the cork depends on how hard one blows against the cork, whether the stream of air hits the upright ends or the round surface of the cork, and whether it is a larger or smaller cork. The larger cork has a larger surface to blow the air against and thus may move faster, even though it is slightly heavier than the smaller cork. Other variables influencing the speed might be investigated like: the type of liquid, the angle of air flow, etc.

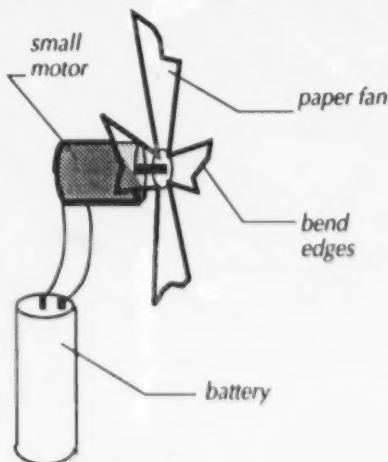
This demonstration shows that moving air is a form of energy: kinetic energy of moving air molecules. An example in daily life would be the sail boat, where the wind is actually pushing against the sail to move the boat forward.

## 1.2.15. THE PAPER FAN

- What you need:**
1. A paper card (5 x 8") or construction paper.
  2. A small DC motor & battery (for activity A).
  3. Straight pins and cello tape (for activity B).

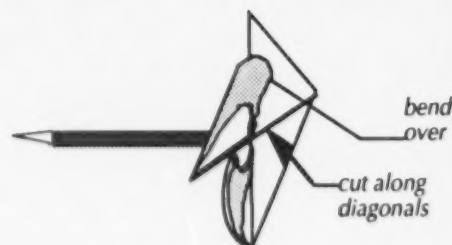
**How to do it:**

1. Cut a circle (12 cm/5" diameter) out of the paper card.
2. Draw four diameters perpendicular to each other on the circle and cut in with scissors till about 1 cm from the center.



Sketch A

3. Cut four sections off and bend the edges of the remaining sections (see Sketch A), and attach this fan to the small motor. Switch the motor on (connect to battery): a flow of air is created.
4. For activity B no motor is needed. Cut a square piece out of construction paper, draw the diagonals and cut along these lines till about 2 cm from the center.
5. Fold every other point back to the center and hold them in by pushing the straight pin through the points and the center of the paper.
6. Push the pin into the eraser part of a pencil and hold the paper mill in a stream of air, or move it back and forth in the air (Sketch B).



Sketch B

**What questions to ask:**

1. What type of energy was transformed into the air flow in activity A?
2. Which way would the wind blow if the fan were turning in the opposite direction (in activity A)? How can we make the wind blow harder without speeding up the motor?
3. What type of energy did the air flow in activity B create?
4. What is needed to make the paper mill in activity B turn?

**How to explain it:**

In activity A electric energy was transformed into mechanical energy: the moving of the paper fan. This in turn made the air flow, which is **kinetic energy of the air molecules**. If the fan would turn in the opposite direction, the air flow would also be reversed. To increase the flow or air without speeding up the motor, we can slant the blades more (make the pitch of each of the blades a little stronger).

With activity B, the kinetic energy of the air flow is transformed into mechanical energy: the turning of the paper mill. In order for this mill to turn, wind or a moving flow of air is needed. The faster this flow of air, the faster the wind mill is turning.

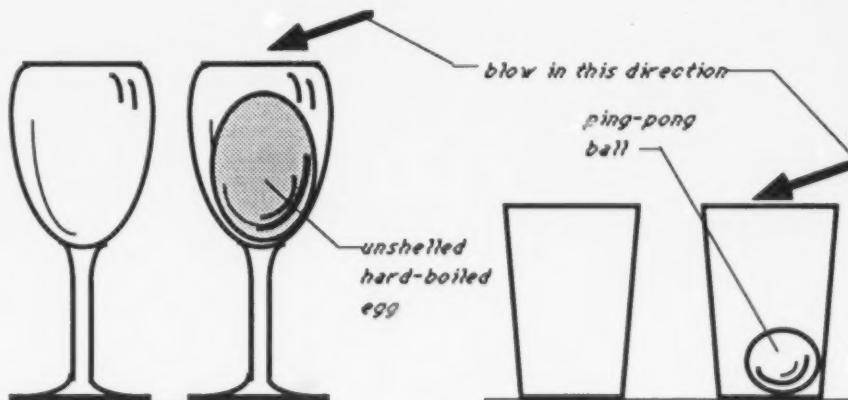


1.2.16. **THE LEAPING EGG**

- What you need:**
1. Two identical wine glasses (or plastic cups).
  2. A hard-boiled egg (or ping-pong ball).

**How to do it:**

1. Place the two wine glasses or cups about 2-3 cm apart on the table and secure them down with tape or just hold them down.
2. Put the hard-boiled egg in one of the glasses (or the ping-pong ball in one of the cups) and ask the audience the question: "How can I move the egg (or ball) from one glass into the other without touching the egg and leaving the glasses as they are?"
3. Most people will respond with: "It's impossible!" Now blow a short and hard puff obliquely into the far side of the wine glass that holds the egg or ball and watch the egg leap! (It may take a few practice blows to make the egg leap successfully).



**What questions to ask:**

1. What makes the egg or ball jump out of the first glass?
2. Why would the egg or ball not go toward the one that blows?
3. What does flowing air create?
4. How far apart can we place the second glass in order for this one still to catch the leaping egg or ball?
5. What would happen if we blew on the near side of the egg or ball?

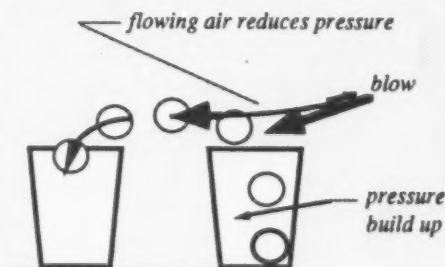
**How to explain it:**

Blowing obliquely into the far side of the glass builds the pressure on that side. It pushes the egg or ball out of the glass and the flowing air above both glasses guides the egg towards the second glass, because the flowing air actually creates a lower pressure. The harder we blow, the farther the second glass can be placed to catch the leaping egg. (**Warning: do not try this activity with a raw egg!**)

Again, this is an application of **Bernoulli's Principle**, which states: **the faster the flow of a fluid, the lower the pressure.**

$$P + \frac{KE}{V} = \text{Constant}, \text{ where } P=\text{pressure, } KE=\text{Kinetic Energy of fluid}$$

and  $V$ =volume of fluid



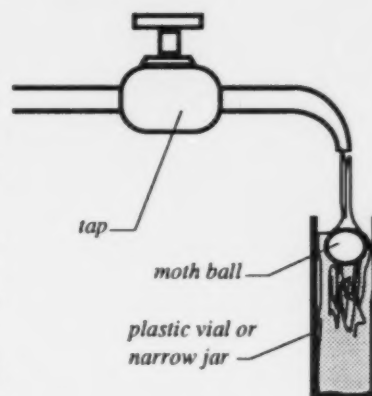


1.2.17. **LIFT A MOTH BALL WITH STREAMING WATER**

- What you need:**
1. A small plastic vial (medicine vial or narrow jar).
  2. A moth ball (or raw egg plus a small drink glass).
  3. A water tap above a sink.

**How to do it:**

1. Place the moth ball in the vial (or egg in the small glass), then ask the students: "How can I lift the moth ball (or egg) up without turning the vial or glass upside down?"
2. Now open the tap and let the water run with a smooth medium size flow (this should be tried out beforehand so that you know what size stream you need for the lifting power).
3. Hold the vial with the moth ball or glass with the egg under the water stream, such that the water falls directly on top of the ball (or egg). Observe the ball (or egg) rise to the water surface!

**What questions to ask:**

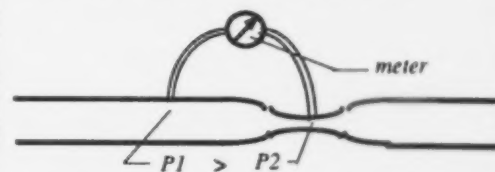
1. What made the moth ball rise up in the water?
2. Does a moth ball sink or float in water?
3. What happens if the water flow is suddenly stopped?
4. Would the moth ball keep floating if the water keeps running?
5. What would happen if the water stream was not falling head on?
6. What would happen to the ball if we used a larger/wider jar?
7. What happens if we used a stronger or weaker flow of water?
8. After the ball got lifted to the top, what would happen if the water stream were increased or decreased?
9. What happens to the ball if the vial was held in a slanted position?

**How to explain it:**

**Bernoulli's Principle states: the faster the fluid flow, the lower the pressure.** In this case the fluid is the water streaming out of the tap. The faster this flow of water, the lower the pressure, but the larger the downward force. This means that there is an optimum flow where it creates a low enough pressure above the ball. This makes the ball rise up with the water flow until it reaches the surface.

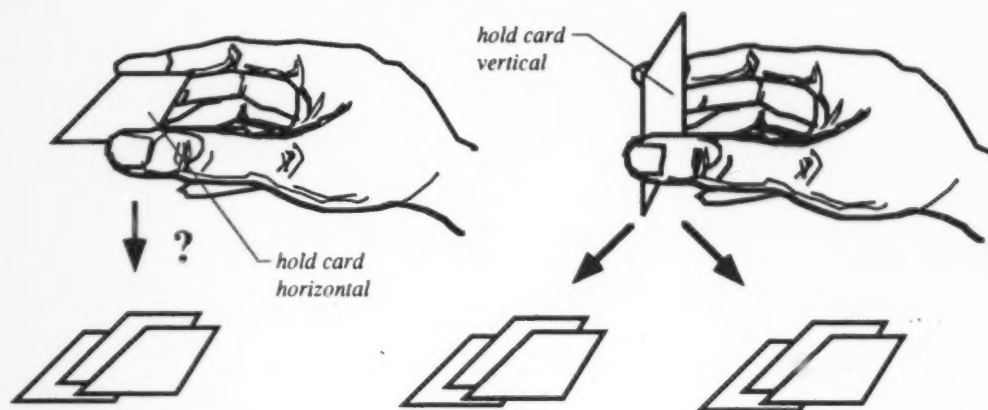
A sudden stop of the water flow will make the moth ball sink, showing that indeed the lower pressure created by the water flow was the cause for the ball going up. Increasing the water flow will also make the ball sink, but this time because of the downward force of the water.

A technological application is the **Venturi tube**, a measuring instrument for fluid speed based on this same Bernoulli's Principle (See Sketch on right). The difference in pressure between the smaller tube (P2) and the larger tube (P1) will indicate the speed of fluid flowing through the tube.



## 1.2.18. THE SELF DIRECTING CARDS

**What you need:** 1. A deck of playing/bridge cards.

**How to do it:**

1. Stand up straight with a deck of cards in your hand. Hold one card at a time in front of you between two fingers horizontally and ask: "Where do you think this card will end up on the floor? Straight underneath it or off to the side?", then drop the card. (See Sketch A).
2. Hold the next card between thumb and index finger by the short sides, vertically with a slight slant to the left; ask the same question, then drop the card (See Sketch B).
3. Hold the next card the same way, but now slant it slightly to the right, ask: "Where will this card end up on the floor?", then drop the card.

**What questions to ask:**

1. Where did the first, second and third card end up on the floor?
2. What made them fall so differently?
3. Which of the cards stayed steady while falling?
4. How could you separate the cards into three equal piles by dropping them to the floor? (This question could be used before doing the demo).
5. What do you think would happen if you held the cards by the long sides and let them fall from the three different positions?
6. What do you think the cards would do when dropping two at a time?
7. Where would the cards end up on the floor, if the cards were held in a random fashion before dropping?

**How to explain it:**

When letting the card fall horizontally, it will stay horizontal and end up quite plumb underneath the position before falling. This is caused by the even flow of the air around the card. When holding the card vertically, the leading edge of the card cuts into the air, encounters a slightly higher pressure or resistance on one side, flips up, and the card starts rotating. Once it spins it will keep on spinning. The ones slanted to the left will rotate in a clockwise direction, and the ones slanted to the right will rotate counter-clockwise (from the point of view of the performer). This demonstration must be done in a draft-free room. It will not have the same results outdoors. On a windy day, dropping the cards will have the same random result as holding the cards at random positions indoors before dropping them.

*Don't be afraid to show your own  
excitement  
and  
enjoyment !*



*Showing a Fire-cyclone or Fire-tornado.*

## CHAPTER 3

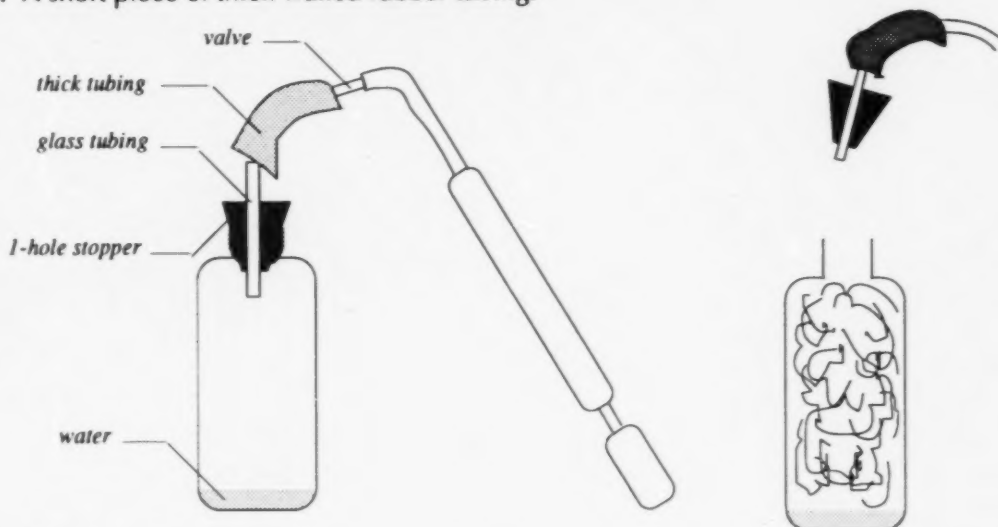
### WHAT FACTORS INFLUENCE THE WEATHER ?

**After dealing with and studying the concepts and sub-concepts in this chapter, the students should be able to:**

- a. Recognize the correct explanation of the influence of atmospheric pressure, wind speed and direction, and humidity on the weather;
- b. Explain correctly in their own words how atmospheric pressure, wind speed and direction, temperature and humidity are measured;
- c. Distinguish true from false statements concerning each one of the variables influencing the weather;
- d. Identify the correct explanation concerning variables that influence the climate, length of days, and the sun's heat.

## 1.3.01. A CLOUD IN A BOTTLE (I)

**What you need:** 1. A colorless transparent soda pop bottle. 2. A bicycle hand pump & bicycle tire valve. 3. A 1-hole stopper with short glass tube (fitting the bottle). 4. A short piece of thick walled rubber tubing.

**How to do it:**

1. Place a few millilitres of water in the bottle.
2. Insert the 1-hole stopper tightly in the bottle opening and connect the bicycle pump as shown in the sketch.
3. Pump air into the bottle and let the students observe the bottle very carefully, especially the moment when the stopper pops ours.
4. When the cloud is not too visible, drop a lit match in the bottle or blow a little smoke in the bottle, then repeat point 3.

**What questions to ask:**

1. What do we need the water in the bottle for?
2. At the moment that the stopper pops out, what does the air inside the bottle do?
3. At the moment that the stopper pops out, what is the temperature of the air inside the bottle doing?
4. What will water vapor do when it is cooled?
5. Why do we get a better cloud with a little smoke in the bottle?
6. Where do we see applications of this principle (with the smoke) in our daily life?

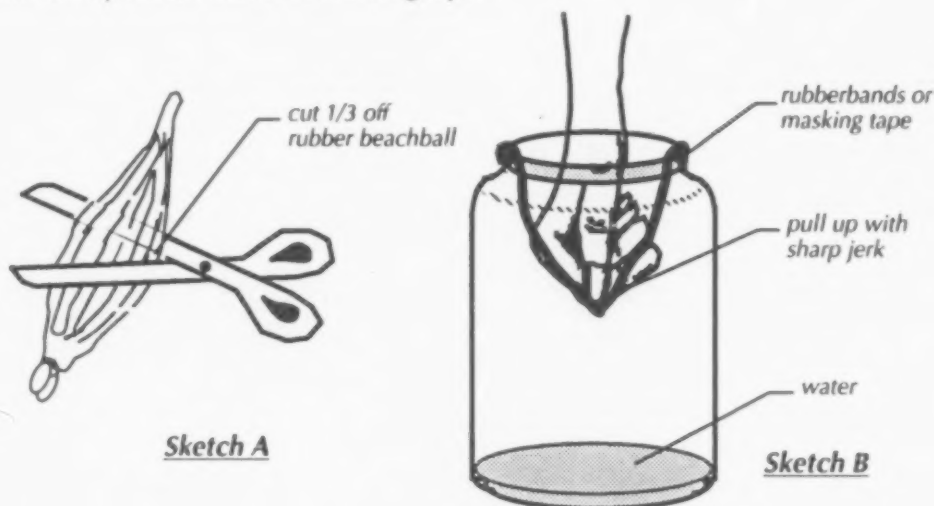
**How to explain it:**

At the moment that the stopper pops out, we get a sudden low pressure in the bottle. The miniature atmosphere in the bottle had a high humidity because of the presence of the water. At the moment that the stopper pops, the air in the bottle rushes out, the temperature drops as air expands, and the **water vapor condenses**. This condensation process is enhanced by the presence of smoke, which is a suspension of solid particles in the air acting like **nuclei** for the water vapor to condense on. This is the reason why it is more likely that it will become foggy or rainy over polluted areas, such as larger cities with heavy industry, than over rural areas that have no industry.



1.3.02. **A CLOUD IN A BOTTLE (II)**

- What you need:**
1. A wide mouth gallon jar (pickle jar).
  2. An uninflated rubber beachball.
  3. Same heavy rubber bands or masking tape.

**How to do it:**

1. Place a few millilitres of water in the gallon jar.
2. Drop a lit match or blow some smoke in the jar.
3. Cut one third off of the beachball (Sketch A) and turn the larger part inside out. Place it over the jar, such that the cut edge slips over the rim of the jar, then fasten it with a few heavy rubber bands or masking tape around the jar mouth (make sure it is airtight).
4. Pull the rubber sheet up with a short sharp jerk and observe what is happening in the jar (see Sketch B).

**What questions to ask:**

1. What function does the water in the jar have?
2. What do we need the smoke in the jar for?
3. What is suddenly increased by pulling the rubber sheet up?
4. How does the pulling of the rubber sheet affect the temperature?
5. Why is it usually more cloudy and foggy over industrial areas as compared to rural areas?
6. What would happen if the rubber sheet was not put on the jar airtight?
7. Would the cloud be more easily formed if the bottle were warm or cold?

**How to explain it:**

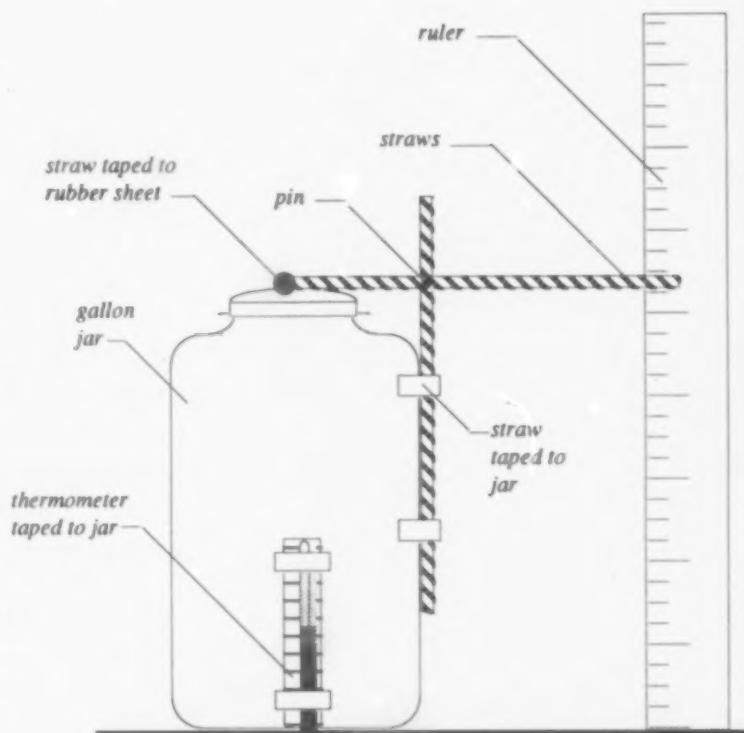
The water in the jar is necessary to create a miniature atmosphere with a **high humidity**. The smoke provides the nuclei on which the water vapor can condense when the rubber sheet is suddenly pulled up. This pulling up of the rubber sheet causes the volume of the air inside the jar to suddenly increase, and thus the temperature to decrease. As the humidity is very high, the air contains the maximum capacity of water vapor. The slightest drop in temperature, therefore, is enough to cause the water vapor to condense and produce a mist or fog.

## 1.3.03. THE JAR BAROMETER

- What you need:**
1. A wide-mouth gallon jar (pickle jar).
  2. A large balloon, 2 straws, a straight pin.
  3. A ruler, masking tape, a thermometer.

**How to do it:**

1. Blow the balloon up (preferably a day before use or a few hours before use) so that the rubber is stretched.
2. Cut a piece off the stretched balloon (large enough to cover the jar opening) and tape it airtight to the jar mouth.
3. Tape two straws pivoted with a pin to the center of the rubber sheet and to the side of the jar (see Sketch).
4. Place the jar such that the straw indicator points along a ruler.
5. Place a thermometer close to the jar or tape it to the jar, and read the pressure off the ruler at the same temperature, twice a day.

**What questions to ask:**

1. When the atmospheric pressure gets higher, will the reading on the ruler be higher or lower?
2. Why is it necessary to stretch the rubber sheet beforehand?
3. Why does the reading of the pressure have to be done at the same temperature? What would a higher temperature do to the reading?
4. What does an increasing atmospheric pressure indicate for the weather forecasting?
5. What does a decreasing atmospheric pressure indicate?

**How to explain it:**

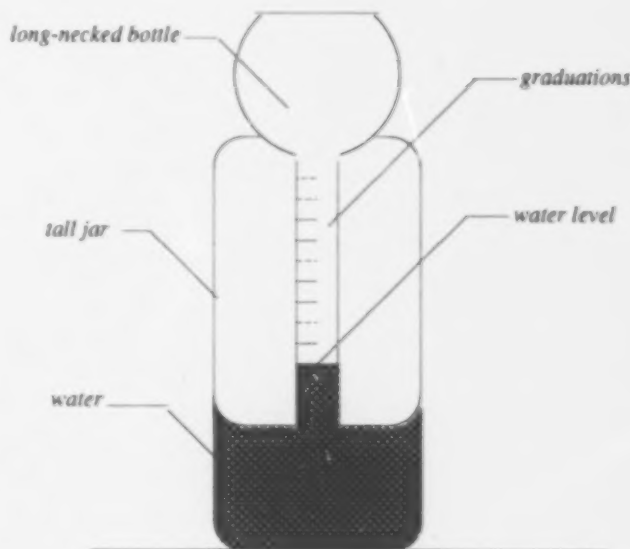
This simple barometer is only good for measuring **relative atmospheric pressure changes**. The ruler could be calibrated by listening to radio announcements of atmospheric/barometric pressures. The rubber diaphragm is more sensitive to pressure changes, when it is more flexible; that is why it needs prestretching. The reading of this simple instrument has to occur at the same temperature, as an increase in temperature will result in expansion of the air inside the jar, and thus a higher pressure in the jar and a lower reading. Cooling of the jar results in contraction of the air in the jar and thus a higher reading.

## 1.3.04. THE BOTTLE BAROMETER

- What you need:**
1. A bottle with a long narrow neck.
  2. A cylindrical tall jar & thermometer.
  3. A grease marker (a felt marker will do).

**How to do it:**

1. Find a bottle with a long narrow neck and a jar that can support the wider part of the bottle when inverted in the jar (see sketch).
2. Draw horizontal even graduations on the bottle neck with a marker and assign numbers to the graduations (hold bottle upside down).
3. Fill the jar half full with water.
4. Pour some water in the bottle and invert it quickly into the slanted held jar, so that the water level in the bottle neck will be slightly higher than that in the jar.
5. Position the bottle barometer in a place where the temperature does not fluctuate, and read off the water level in the neck. Do this twice a day and compare readings.

**What questions to ask:**

1. What should the water level in the bottle neck do if the atmospheric pressure increases? If it decreases?
2. Why does the barometer have to be put in a place where the temperature does not fluctuate?
3. At what point do these bottles function as a barometer?

**How to explain it:**

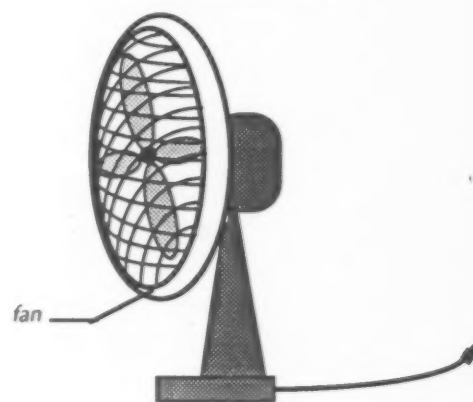
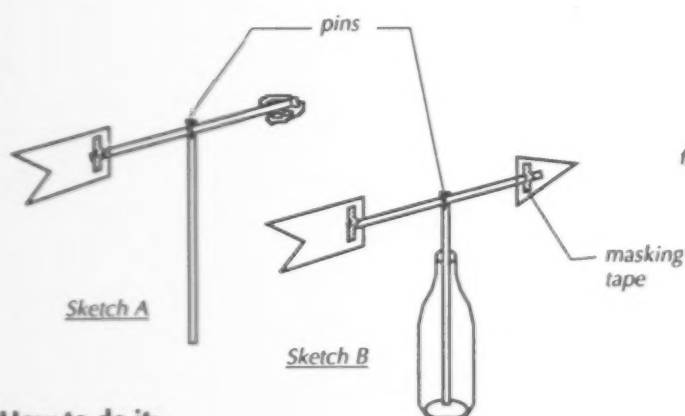
When the **atmospheric pressure** increases, the water level in the jar is pushed down and thus pushed up in the bottle neck. When the pressure decreases, the water level in the jar goes up and thus the water level in the bottle neck goes down.

This simple **barometer** will only work when the surrounding temperature stays constant. When the surrounding temperature increases, the bottle and the air inside it warms up and expands, pushing and exerting pressure against the water resulting in a lower reading of the water level. A cooler surrounding temperature has the opposite reaction as a result.

Over a longer period of time, the water of the jar will evaporate and water has to be added to bring the water level back up to its original level, otherwise it ceases to function.

## 1.3.05. WHICH IS THE BEST WINDVANE ?

**What you need:** 1. Drinking straws, straight pins, paper clips  
scissors 3. An empty soda pop bottle. 2. Cellotape, paper cards, clay,  
4. A small electric fan.

**How to do it:**

1. Provide students with straws, paper cards, pins, scissors, cellotape, paper clips (pop bottles if available).
2. Ask students to construct a good working windvane (the best one will turn fastest into the wind direction).
3. Ask students what the conditions are for the windvane to work.
4. If students have trouble making one, give them clues by first constructing windvane A (see Sketch A): Tape a piece of card to the end of a straw and insert some paper clips to the other end, find the balancing point (by letting it balance on your finger) and stick a pin through the straw at that point (the center of gravity). Let this straw swivel around a vertically held straw (set in a pop bottle: Sketch B)

**What questions to ask:**

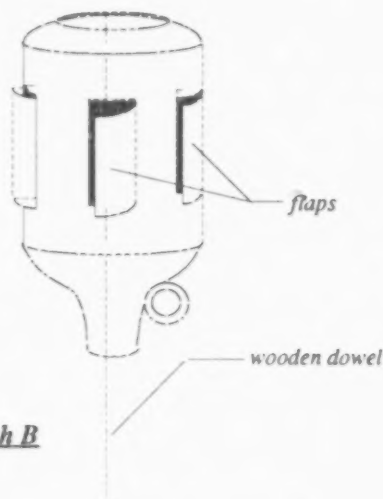
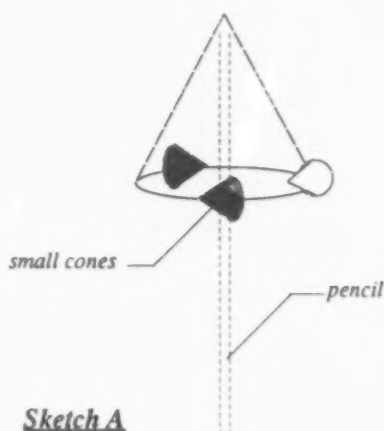
1. What is the difference between the front and the rear part of the windvane? Is there a difference in area? In weight?
2. What must the horizontal bar be able to do to turn in the direction of the wind?
3. Where must the pivot of the arrow (horizontal bar) be located?
4. What can be used as a base or stand for the windvane?
5. How would you construct a windvane that points where the wind is blowing to (opposite to where it comes from)?

**How to explain it:**

In order for a windvane to work, one end must be **wider in surface area** than the other end. By taping a cut-out card to one end of the straw, we increase the area at this end, but the weight at this end is thereby also increased. To counterbalance this, paper clips are inserted at the other end. This makes it possible to place the pivot in the center of the bar.

## 1.3.06 HOW FAST DOES THE WIND BLOW ?

- What you need:**
1. Paper cards (3 x 5"), cellotape, scissors.
  2. An empty plastic bottle with a narrow neck.
  3. A wooden stick (round), knife, nail.
  4. A small electric fan.

**How to do it:**

1. Fold four paper cards into cones and cut them into one large and three small cones. Tape the small cones to the edge of the larger cone, pointing in the same direction. Let the large cone swivel around a pencil or pen by holding it in the wind of the fan (see Sketch A).
2. Cut slits in the side of the plastic bottle and bend the flaps slightly outward. Make a small hole in the bottom of the bottle, turn it upside down on the stick and nail it loosely on the end of the stick so that the bottle can swivel easily (see Sketch B).
3. Color one of the small cones and one of the flaps of the plastic bottle red or black. To calibrate the instrument, hold it out a car window when the car moves with a speed of 20, 30, 40, 50 km/h and count the number of revolutions for each of the velocities (do this on a day when there is no wind blowing).

**What questions to ask:**

1. Will anemometer A turn in the same direction as B (see Sketch)?
2. How can we measure the wind speed with this (B) anemometer?
3. Does it matter where the wind comes from when using this anemometer?
4. In calibrating the instrument, why do we have to wait for a day when there is no wind?
5. What makes the anemometer turn only in one direction?

**How to explain it:**

The **anemometers** as shown in the sketch will turn in opposite directions. The simple anemometer turns only in one direction when held in a stream of air, because the air resistance on one side of the cone or cylinder is less than on the opposite side. After calibrating the instrument, it is just a matter of counting the number of revolutions to tell how fast the wind blows. A day with no wind should be chosen to calibrate it, as the existing wind will otherwise affect the reading.

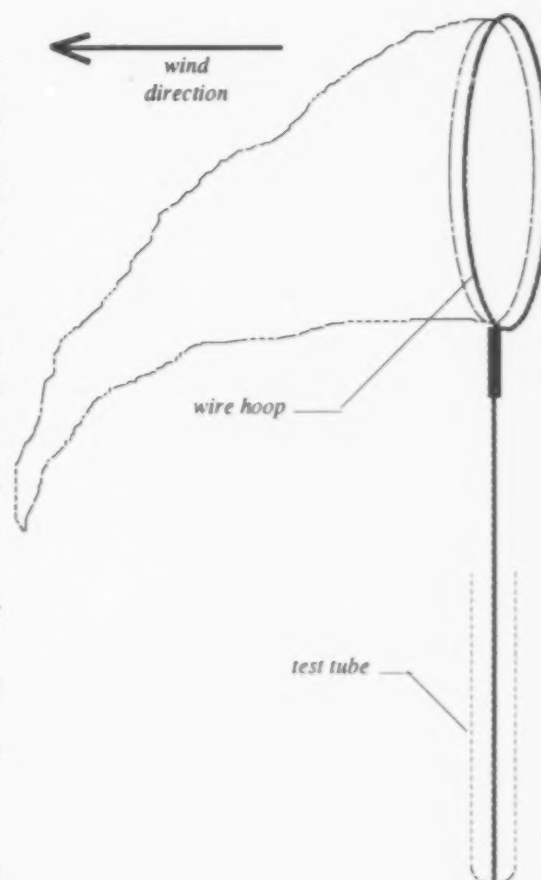


## 1.3.07. FIND WIND SPEED AND DIRECTION TOGETHER

- What you need:**
1. A nylon stocking & a medium size wire (about 80 cm) (or a coat hanger).
  2. A narrow test tube (or jar) & a small electric fan.

**How to do it:**

1. Make a hoop (circle) with a 10-15 cm diameter from one end of the wire (coat hanger), and let the other end protrude for at least 20 cm.
2. Fold the edge of the opening of the stocking around the hoop and tape it secure to the hoop (this can also be done by sewing or melting the nylon together).
3. Stick the protruding end of the wire into the test tube (or through a hole in the lid of the jar) and make sure it can swivel freely in the tube or jar.
4. Bring the "wind-anemo-vane" in the wind stream of the fan or place it outside in the ground on a windy day.

**What questions to ask:**

1. What other material can be used instead of the stocking?
2. Why does the stocking turn away from the wind?
3. How can we tell the speed or velocity of the wind?
4. How would you calibrate this instrument?
5. What is a wind velocity meter called?
6. Why is the measuring of the wind speed important?
7. What do we need in order to forecast the weather?

**How to explain it:**

The stocking or strips of paper in the wind will act just like a flag in the wind. It will wave away from the wind, similarly the stocking will point in the direction where the wind is going to and not where it is coming from. The **windvane**, on the other hand, is pointing into the wind, opposite to what the stocking is doing.

The stocking may be called a "**wind-anemo-vane**" because it does both: indicating the direction and the speed of the wind. The instrument measuring the speed of the wind is called: **anemometer**. The more horizontal the stocking, the stronger the wind is.

Measuring the wind speed and direction is very necessary in the forecasting of the weather. These socks - in much large size - are placed in most airports, so that pilots have a rough idea where the wind comes from and with what speed.

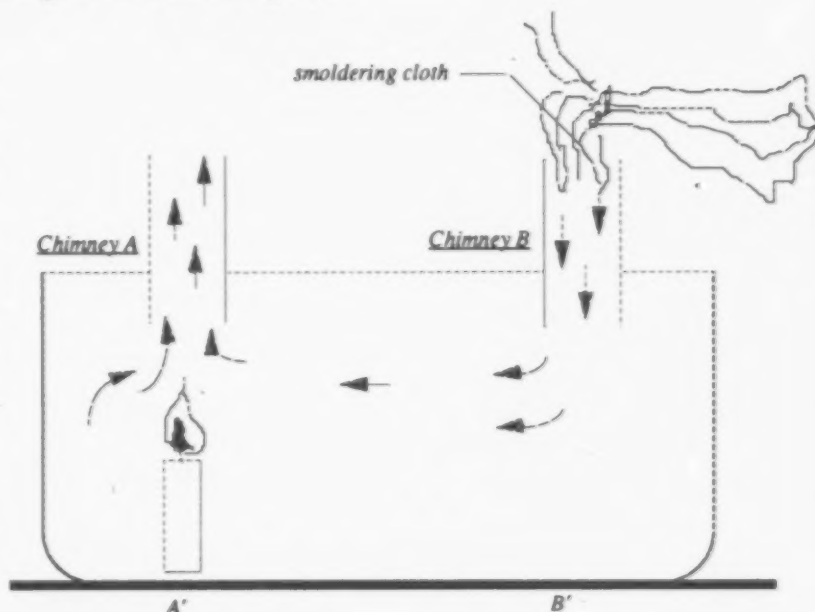
## 1.3.08.

## CREATE WIND CURRENTS

- What you need:**
1. An empty aquarium or any large transparent container.
  2. Thin cardboard (bristol/poster board or manila folders).
  3. Black poster board or black carbon paper.
  4. A small candle, an old rag, matches, masking tape.

**How to do it:**

1. Make a cover for the aquarium with two holes, and also two fitting pipes, that will act as chimneys, from the thin cardboard.
2. Cover the backside of the container with black paper, so that the smoke currents can be more easily seen (use a spotlight if available).
3. Fix the candle under one of the holes in the bottom of the aquarium and light the candle.
4. Place the cover over the container and tape the edges airtight to it.
5. Make a smoke source from the rag (by burning it and letting it smolder) or light a cigarette, and hold the smoke close to chimney B (see Sketch).
6. Let the smoke fall into chimney B (do not hold the smoke source directly above the opening, but blow the smoke over the opening) and let the students observe the smoke currents.

**What questions to ask:**

1. What makes the smoke fall in chimney B?
2. Why does the air rise through chimney A?
3. What is the purpose of the burning candle?
4. How can we create wind currents without the burning candle?
5. What places on earth can spot A' and B' be compared with?

**How to explain it:**

The burning candle is a source of heat. It heats the air above and around the flame, and **heated air rises**. This makes the air rise through chimney A, and because air goes out of the container, air must replace it, and this comes in through chimney B, taking the smoke with it. Spot A' can be compared with a hot place on earth (f.i. the tropics) and B' with a cold place (the poles). The air currents or winds are created this way between such places on earth. Instead of the candle, we can also use an ice cube above chimney B. Cold air will move down and create the same currents.

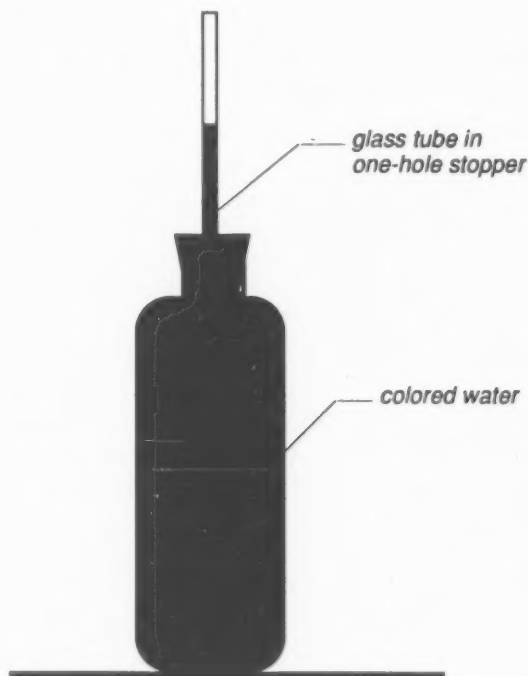
1.3.09.

**MAKE YOUR OWN THERMOMETER**

- What you need:**
1. A small soda pop bottle & food coloring or ink.
  2. A transparent plastic straw or glass tube.
  3. A clump of clay or a one-hole stopper.
  4. An alcohol burner & stand, or a candle.

**How to do it:**

1. Fill the pop bottle full with cold water and color it with a few drops of food coloring or ink.
2. Put some clay around the straw or insert the glass tube in the one-hole stopper (make sure that only a short end will go in the bottle).
3. Immerse the straw or glass tube in the water-filled bottle, insert the stopper and mark off the water level in the straw or tube.
4. Heat the pop bottle or cool it down with an ice cube and let students observe the change in water level.

**What questions to ask:**

1. Why does the straw or glass tube connection to the bottle have to be watertight?
2. What will heating or cooling do to the water level in the tube?
3. How similar is this instrument to a real thermometer?
4. How could we calibrate this simple instrument?
5. Could this instrument actually be used to measure temperatures?

**How to explain it:**

The small soda pop bottle can be compared to the bulb of a regular thermometer. The larger this bulb, the more sensitive the thermometer is: thermometers for measuring body temperature have large bulbs and narrow tubes. Heating the bottle will result in heating the liquid and thus expanding it, causing the liquid level in the tube to get higher. Cooling the bottle causes the liquid to **contract**, resulting in a lower reading level. Calibrating of the bottle thermometer can be done by immersing the bottle in melting ice ( $0^{\circ}\text{C}$ ), marking the water level; then leaving the bottle at room temperature for some time ( $20^{\circ}\text{C}$ ), marking the water level in the tube, then dividing the space between the two marks by 20 for each degree Celsius.

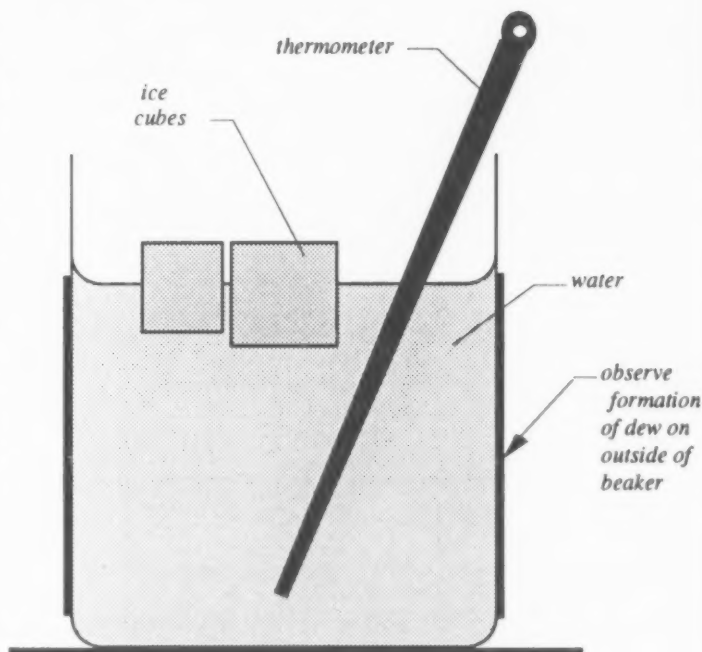
1.3.10.

**AT WHAT TEMPERATURE IS DEW FORMED ?**

- What you need:**
1. A beaker or regular drinking glass.
  2. A thermometer ( $-5^{\circ}$  to  $50^{\circ}$  or  $100^{\circ}$  C).
  3. Ice cubes.

**How to do it:**

1. Fill the beaker/glass almost full with water and add a few ice cubes.
2. Keep track of the temperature of the mixture of water and ice and observe carefully the outside of the beaker or glass.
3. Stir the mixture once in a while with the thermometer (carefully) and note the temperature at which the dew is first formed on the outside of the glass (look for a dullness on the glass).

**What questions to ask:**

1. Where does the dew on the outside of the glass come from?
2. At what temperature was the dew formed?
3. Is there always the same amount of water vapor in the air?
4. Will the dew point be higher or lower on humid days?
5. Where do we encounter a similar event inside the house in winter?

**How to explain it:**

The ice cubes in the water are cooling the mixture slowly down and depending on how much moisture there is in the air, the sooner or later the **water vapor will condense** on the outside of the beaker; thus the higher or lower **the dew point** will be respectively.

The drier the air around the beaker is, the lower the temperature has to be, before any water vapor will condense on the beaker's surface, and thus the lower the dew point.

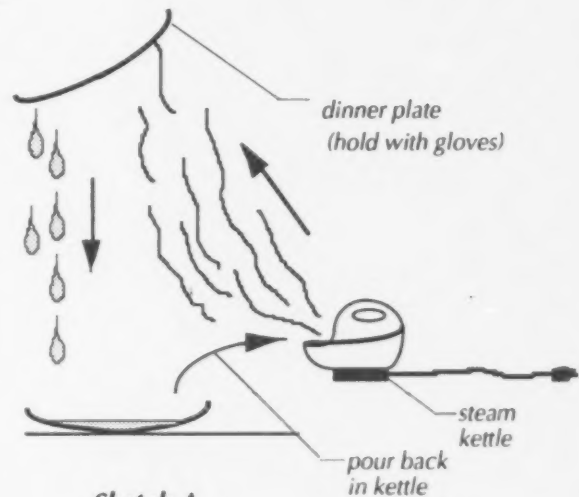
Just after a rainfall the air is very humid, meaning that this percentage of water vapor in the air is high, and thus the dew point is also high. On dry days or in areas of low humidity, the temperature has to drop quite low before any dew drops are formed on the grass in the morning.

## 1.3.11. RECYCLE THE WATER

**What you need:** 1. Two shallow trays or regular dinner plates.  
2. Electric water kettle.

**How to do it:**

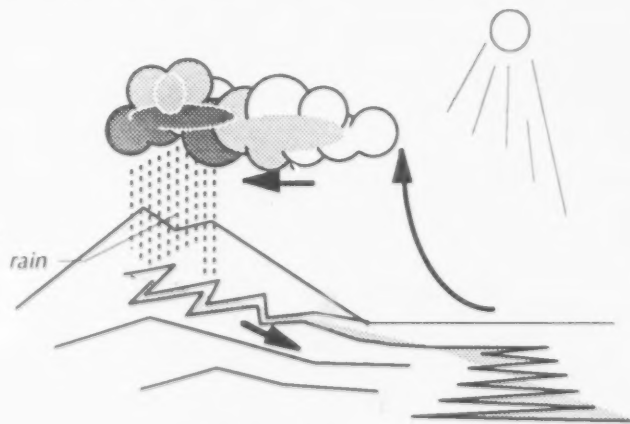
1. Heat water in a kettle until boiling.
2. Suspend a tray or plate in the steam or water vapor that comes from the kettle, and place the second plate under the first to catch the water drops (condensate). (Put cold water on the first plate).
3. Pour the water from the second plate back in the kettle to complete the cycle.

*Sketch A***What questions to ask:**

1. What made the steam or water vapor turn back into water?
2. Would the steam also condense if the top plate was filled with hot water?
3. What are conditions for clouds to turn into rain?
4. What makes the water evaporate in nature?
5. What can the pouring back of water from the lower plate into the kettle be compared with in the natural water cycle?

**How to explain it:**

The steam or **water vapor** is produced in the kettle, because the water in the kettle is heated. When the steam hits the cold plate, it **condenses** back into water. The kettle can be compared to the ocean water being heated by the sun rays. The water vapor accumulates in the higher layers of the atmosphere to form clouds. When these clouds move into colder regions, they saturate the air with water vapor and the cold temperatures turn it into **rain condensation**. This may be compared to the steam hitting the cold surface of the first plate. The rain water in nature flows into rivers and these flow back into the ocean (Sketch B).

*Sketch B*

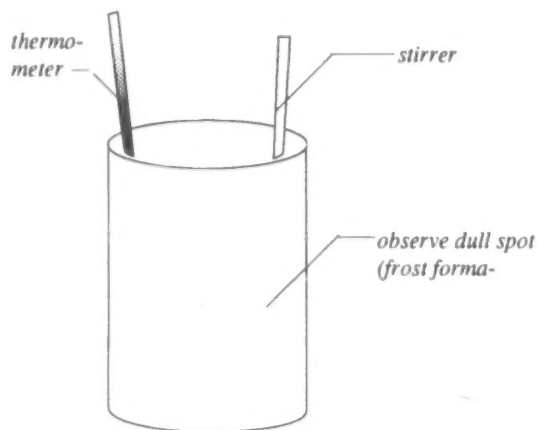


## 1.3.12. THE FROSTY CAN

- What you need:**
1. A tin can (from which the label is taken off).
  2. Crushed ice and coarse table salt.
  3. A thermometer and stirrer.

**How to do it:**

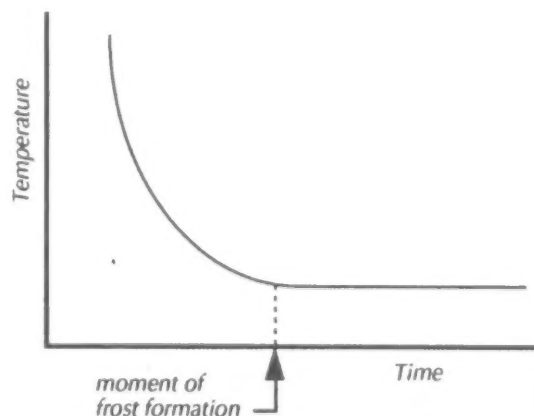
1. Fill the tin can, from which the label is taken off, with crushed ice and a handful of salt.
2. Place the thermometer in the can and stir with a separate stirrer/spoon.
3. Have students read off the temperature every half minute.
4. Have other students (or yourself) observe carefully the outside surface of the can and indicate to those observing the temperature, the moment that they (you) observe frost formation (when the shiny surface gets dull).
5. A further extension of the activity might be the graphing of the data of observed temperature and the time elapsed.

**What questions to ask:**

1. What is the purpose of the salt mixed in with the crushed ice?
2. How low does the temperature inside the can have to be in order to form frost on the outside?
3. What do you expect the temperature of the ice and salt to do after the moment that frost is formed?
4. After observing the shape of the graph after frost formation, what is the process of frost formation doing: absorbing or giving off heat?
5. Where does the frost come from; what is needed in the air?

**How to explain it:**

The salt in the crushed ice makes the ice melt in the beginning, but brings the temperature down below the normal **freezing point** of water ( $0^{\circ}\text{C}$ ). The moisture in the air, hitting the cold surface of the can, turns into the solid state (frost) without passing the liquid state: **sublimation**. This process, just like condensation, is giving off heat, which is why the graph levels off after frost formation (see Graph on the right).

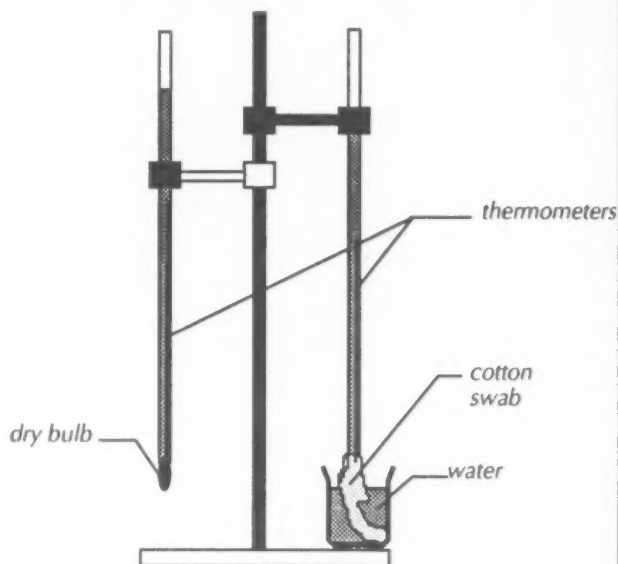


## 1.3.13. THE WET AND DRY THERMOMETER

- What you need:**
1. Two identical thermometers.
  2. A small swab of absorbent cotton, or piece of cotton cloth.
  3. A small beaker/cup, two clamps and stand/clothespins & tape.

**How to do it:**

1. Clamp two thermometers close to each other with the clothespins against a shelf.
2. Have students read off both temperatures.
3. Wrap one thermometer bulb with a small swab of absorbent cotton.
4. Place some water in the small cup and keep the cotton around the bulb wet at all times.
5. Have students read off both temperatures again.
6. Determine the relative humidity from the humidity chart.

**What questions to ask:**

1. Why is there a difference between the dry and the wet bulb temperatures?
2. What causes the wet bulb temperature to decrease?
3. What effect does a higher relative humidity have on the difference between wet and dry bulb temperatures?
4. What can we say about the relative humidity when the difference between the two temperatures is large?
5. What can we say about the relative humidity when the difference between the two temperatures is small?

**How to explain it:**

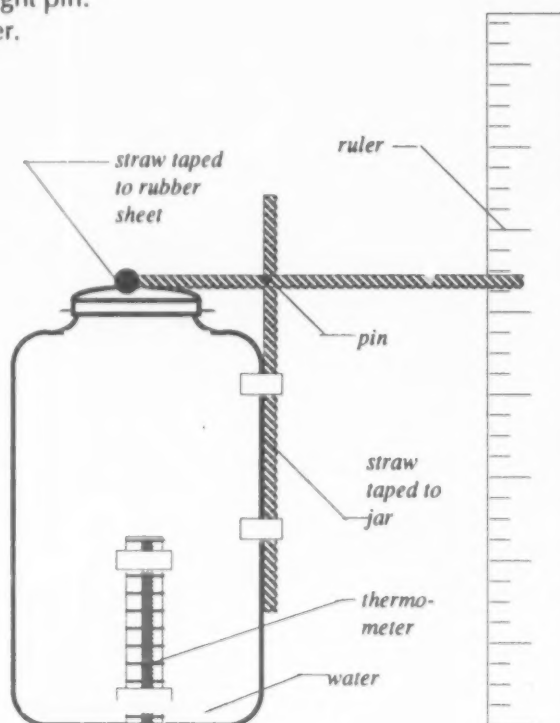
The wet bulb temperature decreases, because the **evaporating water** withdraws heat from its environment. The drier the atmosphere is, the faster the water will evaporate, and thus the lower this wet bulb temperature gets, resulting in a greater difference between the two temperatures. When the relative humidity is high, the dry bulb can almost be considered to be a wet bulb; also the rate of evaporation of the water is much slower, because the air is almost saturated with water vapor. A smaller difference between the two temperatures therefore indicates a high relative humidity (see Humidity Chart in Appendix).

## 1.3.14. THE JAR HYGROMETER

- What you need:**
1. A wide-mouth gallon jar (pickle jar).
  2. A large balloon, 2 drinking straws, a straight pin.
  3. A ruler, adhesive tape, and a thermometer.

**How to do it:**

1. Place a few millilitres of water in the jar.
2. Blow up the balloon (preferably a day or a few hours before use), so that the rubber is stretched.
3. Cut a piece off the stretched balloon (large enough to cover the jar opening) and tape it air tight to the jar mouth.
4. Tape two straws pivoted with a pin to the center of the rubber sheet and to the side of the jar (see Sketch).
5. Place the jar such that the straw indicator points along a ruler.
6. Place a thermometer close to or tape it to the jar, and read the humidity off the ruler at the same temperature, twice a day.

**What questions to ask:**

1. When the humidity gets lower, will the reading on the ruler be higher or lower?
2. What is the relative humidity inside the jar?
3. What is the absolute humidity as compared to the relative humidity?
4. How will an increase in temperature affect the relative humidity reading on this instrument?
5. What is a most comfortable relative humidity to maintain?
6. How can we increase the humidity in our homes in the winter?

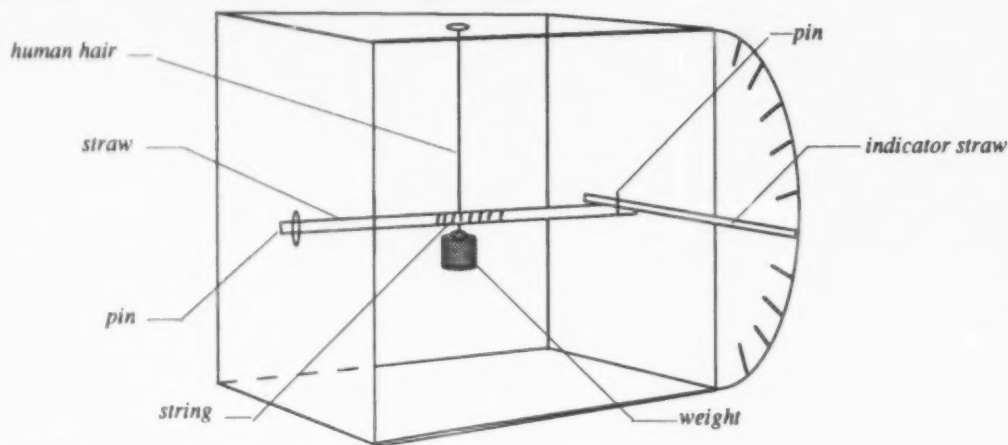
**How to explain it:**

The hygrometer only measures the relative humidity in the air. The absolute humidity is the actual amount of water vapor that the air holds at a particular temperature. The presence of the water in the jar makes the relative humidity 100%. This means that the air inside the jar cannot hold more water vapor: it is **saturated** with water vapor. This miniature atmosphere is being compared with the outside atmosphere. The less humidity in the atmosphere, the more the rubber diaphragm will bulge up, and thus the lower the reading. The term **relative** comes from this comparison with the maximum capacity of the air in holding water vapor.

A comfortable relative humidity is about 60 - 70%. In the winter time the humidity is usually very low, because the moisture in the air has been frozen and precipitated out. To increase this humidity in the house, we can boil water in a pan and let it evaporate or use a humidifier.

## 1.3.15. THE HAIR HYGROMETER

- What you need:**
1. A wooden cigar box, 2 drinking straws, pins.
  2. A long human hair, string, and a weight (20 g).

**How to do it:**

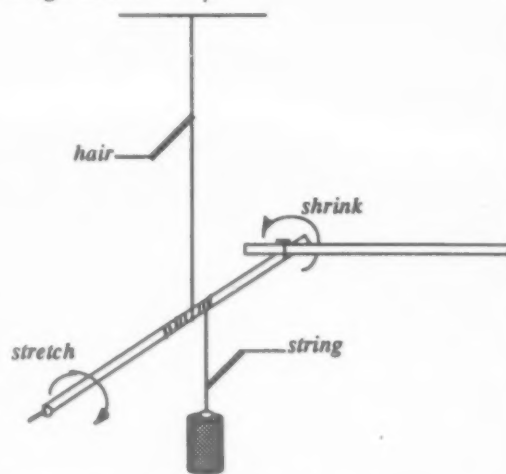
1. Attach a long human hair to the center of the top side of the box, and wind the other end around a horizontally rolling straw, turning freely around pins at each end (see Sketch) and tape the end of the hair to the straw.
2. Now tape a string or thread to the same straw and wind it such that the weight on the other end of the string will pull the hair straight.
3. Attach another straw perpendicular to the first one with a pin or tape. Attach a semi-circle cardboard to the side of the box closest to the indicator straw (draw some graduations on the edge of the semi-circle beforehand) (see Sketch).
4. Read off the relative humidity (position of the indicator straw) and compare with the readings announced on the radio.

**What questions to ask:**

1. What does more or less humidity do to human hair?
2. Does higher humidity cause the indicator straw to go down or up?
3. What is the purpose of the weight?
4. How can we calibrate this instrument?

**How to explain it:**

**Human hair stretches** when the air is humid and **it shrinks** when the air is dry. The weight just keeps the hair tight, thus when the hair stretches, the horizontal straw turns counter-clockwise, and the indicator tip moves higher up. Lower humidity in the air causes it to move clockwise and thus indicate a lower reading. Calibrating of this instrument may be done by listening to radio weather reports and assigning the appropriate values to the graduations.

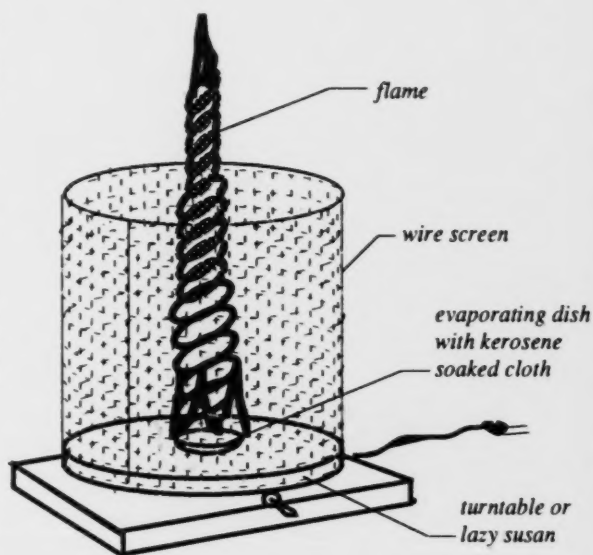


## 1.3.16. MAKE A FIRE CYCLONE

- What you need:**
1. A old turntable/lazy Susan (or a circular wooden board on marbles).
  2. A metal mosquito wire screen (about 30 cm high to fit around the turntable (or the turning wood board).
  3. A small tin can or evaporating dish, cloth, kerosene.

**How to do it:**

1. Roll the wire screen into a cylinder of about the diameter of the turntable and wrap it around the disk, fasten it with tape or with a wire (or both).
2. Soak a small piece of cloth (cotton) or paper in kerosene and place it in the can.
3. Place the tin can or evaporating dish in the center of the turntable.
4. Strike a match and set the cloth on fire, wait till the flame is a good size, then switch the turntable on (or start rotating the lazy Susan/circular board).
5. Observe the flame shape!

**What questions to ask:**

1. What hypotheses/inferences can you make to explain the event?
2. What does a flame need in order to sustain burning?
3. Where does the air come from to reach the flame?
4. In which direction do the air molecules move with respect to the rotation?
5. What shape did the fire take shortly after the rotation started?
6. What could we use instead of kerosene?
7. What event in nature does this resemble?
8. What is the reason for the flame to take that particular shape?

**How to explain it:**

The reason for the flame to be shaped like a **cyclone** is the direction from which the air feeding the flame has to come. Because of the rotating screen around the flame, the air molecules are given an initial **angular momentum** at the moment it enters the screen cylinder from outside. In other words, the screen pushes the air molecules in one direction, in a circular motion. This angular or **rotational momentum** shapes the flame into this cyclone.

In nature, cyclones are formed when two winds of opposing direction pass each other. At the border of the two passing masses of air, a cyclone or **vortex** can be formed. These cyclones are also called **tornados** or **hurricanes**. They are destructive wind storms that can occur over a large area, like hundreds of miles wide. The winds forming the vortex blow spirally inward, creating a low barometric pressure in its center. In the Northern hemisphere these cyclones rotate counter-clockwise and in the Southern hemisphere in a clockwise direction.

These vortices are also formed in water under waterfalls, however, they are not going up but are conically shaped and downward sucking. It is therefore quite dangerous to swim in lakes that are close to waterfalls.

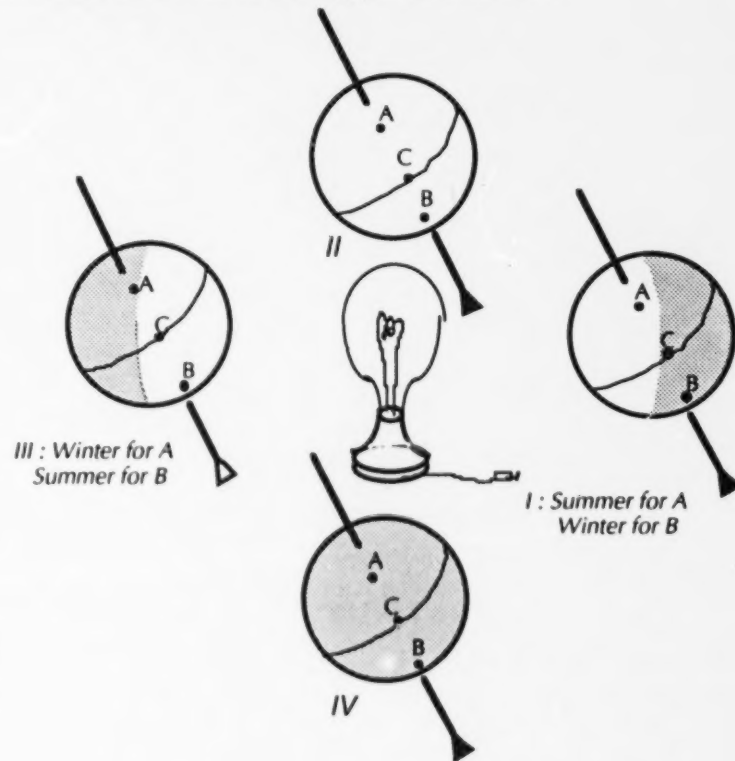


## 1.3.17. WHY LONGER OR SHORTER DAYS ?

**What you need:** 1. A regular glowing light bulb or strong flashlight.  
2. A medium size, smooth rubber ball. 3. A knitting pin and marker.

**How to do it:**

1. Stick the knitting pin through the center of the ball and light the bulb.
2. Hold the ball and knitting pin slanted to the left (top towards the light) at position I; and let the ball spin slowly around the pin.
3. Point out to the students spot A, B, and C (marked on the ball with a marker). Ask: "Which spot gets the most light?"
4. Sequentially, move the position of the ball globe from I to II, to III, and to position IV, and spin the ball around the pin as axis.

**What questions to ask:**

1. At what position is it summer for place A on the globe?
2. At what position is it spring, winter, and fall for place A?
3. What makes the days longer in the summer for North Americans?
4. Why does the sun always set at 6 PM. in a tropical country throughout the whole year?
5. Which point represents a tropical country on the globe?

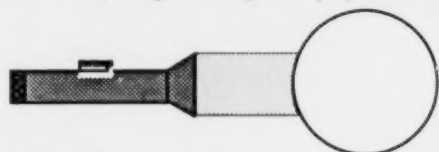
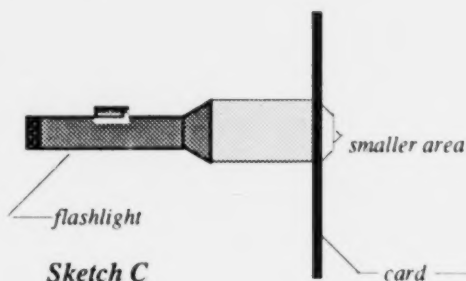
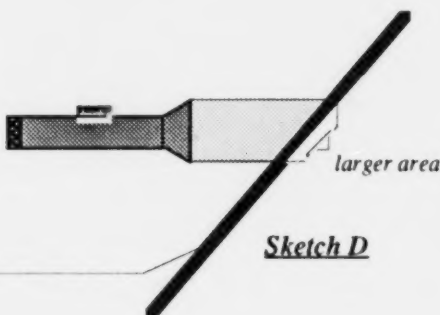
**How to explain it:**

The bulb represents the sun and the ball the earth with the knitting pin as the earth's **axle** (the poles). This **axle**, around which the earth is rotating, is not perpendicular to the plane in which the earth revolves around the sun. This **slanted axle** is the reason why we have four seasons in North America, Australia, and countries at about equal latitudes.

One turn around the axis represents one day and one revolution around the light represents one year. The difference between point A and A should especially be pointed out, at the moment that the shadow reaches one of them when the globe is being spun around its axis. Position I represents summer time, II autumn, III winter, and IV spring for spot A on earth; and winter, spring, summer, and fall respectively for spot B.

## 1.3.18. THE COOL WINTER SUN

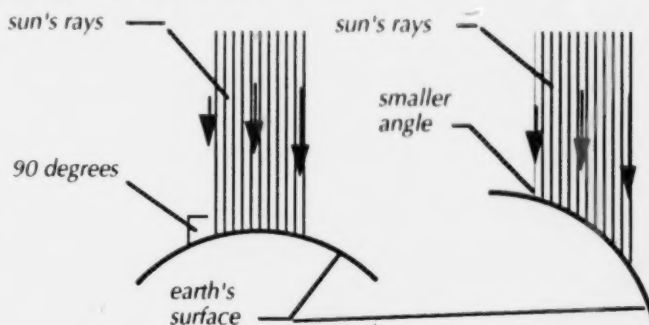
**What you need:** 1. A large smooth ball (without any designs).  
2. A strong flashlight, a paper card or a white cardboard.

*Sketch A: summer sun**Sketch B: winter sun**Sketch C**Sketch D***How to do it:**

1. Shine the flashlight to the center of the ball (Sketch A), then shine it to the edge (Sketch B) and compare the brightness of the light spots.
2. The earth's surface in summer and winter may be compared with the positions of the card. Hold the card perpendicular to the light rays (Sketch C) and slant it away from the flashlight (Sketch D). Observe brightness of the spots.
3. Let students observe the intensity of the light spot on the card.

**What questions to ask:**

1. Which position of the ball or card shows the light less bright?
2. What is different between position A & B, or C & D?
3. Which of the positions has more surface area illuminated?
4. Was the amount of light changed to illuminate more surface area?

**How to explain it:**

When the sun rays strike the earth perpendicular to the surface, they are hotter compared to when they strike the earth in a smaller angle. This is because the same amount of sun is spread out over a larger area. The **intensity** per square area is thus diminished.

The sun's rays in the summer are striking the earth's surface very similarly as the sun's rays strike the tropical areas on earth (**perpendicular**). The angle of the sun's rays striking the earth in winter may be compared with the angle of the sun's rays and earth at sunset. Although the sun's rays and their number do not change, their intensity is always much less at sunrise or during sunset.

*Enthusiasm is contagious*  
*so, show it !*



*Trying to keep a giant bubble afloat.*

## CHAPTER 4

### WHAT ARE THE CHARACTERISTICS OF MATTER ?

After dealing with and studying the concepts and sub-concepts of this chapter, the students should be able to:

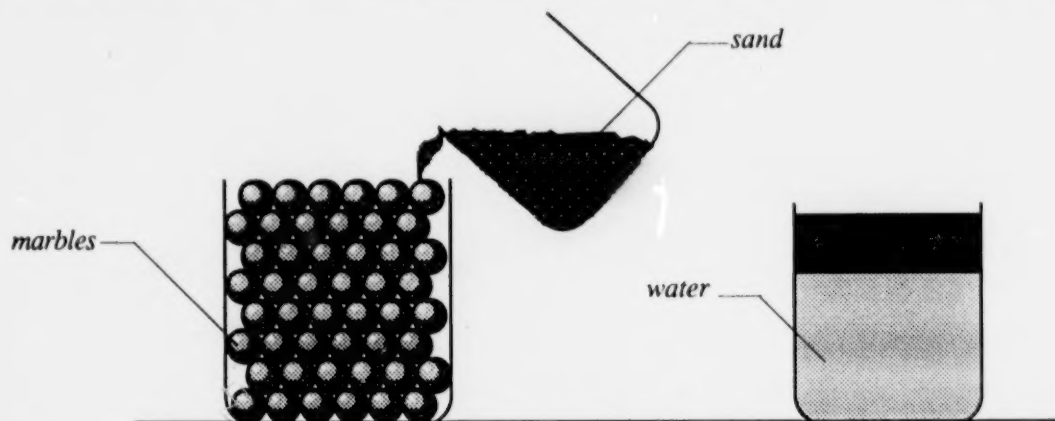
- a. Recognize the correct explanation of an observed event based on each of the sub-concepts.
- b. Explain in their own words which of the sub-concepts is determining the course of an event.
- c. Distinguish true from false statements concerning each one of the sub-concepts.
- d. Identify the correct explanation of an event in daily life applying one of the sub-concepts.

**all in relation to the following sub-concepts:**

- Between the molecules of matter there exists space.
- Matter exists in three states: solid, liquid, and gas.
- Melting and boiling points are specific for pure substances.
- Cohesion is a force that keeps like molecules attracted to each other.
- Adhesion is an attracting force between unlike molecules.
- The forces in a soap film pull at the frame equally in all directions.
- Surface tension exists at the surface of a liquid.
- Surface tension is drastically lowered by soap molecules.
- Density is characteristic for different materials.

1.4.01. CAN THE CONTAINER HOLD MORE ?

- What you need:**
1. A transparent container (glass or plastic).
  2. Marbles, sand and water & a graduated beaker/measuring cup.



**How to do it:**

1. Fill the transparent container up to the brim with marbles.
2. Show the students that you still have sand and water; ask them: "Can I add any other material to this container?"
3. Add sand to the container (shake to settle the sand in between the marbles); ask the same question again.
4. Now add water to the mixture of water and sand.
5. Measure off the amount of sand and water added to the marbles (by measuring how much is left over in a graduated beaker).
6. Do not neglect to tell students that the marbles, sand, and water particles are only illustrating how molecules of matter are behaving and that they are **not** molecules themselves. It is only a model!

**What questions to ask:**

1. Why could the container that was already filled with marbles still hold more sand and water?
2. Could we have started with water, then sand and marbles?
3. What would you infer that the sizes of molecules of different materials or substances would be?
4. What other materials could be used to do this demonstration?

**How to explain it:**

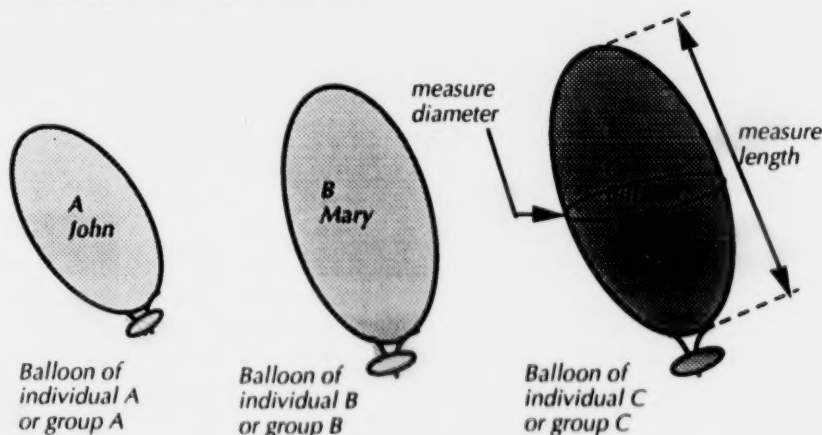
The marbles, sand and water particles are used only as an analogy of how molecules of different sizes would behave, and that there are **spaces in between molecules**. The smaller sized molecules can slip in between the larger ones. Thus it is possible to slip the sand or the water in between the marbles, but not the other way around. It is especially important to point out to students, that the marbles or sand grains are **not** molecules, but that molecules are so small that we cannot see them, not even with a microscope.



1.4.02.

THE SHRINKING BALLOON

- What you need:**
1. A balloon for each of the students.
  2. Flexible measuring tapes or string and meter sticks.



**How to do it:**

1. Divide the class into three groups A, B, and C; distribute the balloons.
2. Have group A blow the balloon up and let about half the amount of air out, group B blow the balloon up and then let about 1/4 of the air out, and have group C leave the balloon blown up fully, and tie a knot in it. (If working with one child: let him/her work with two or three different sizes of balloons).
3. Let each student measure the diameter and length of his or her balloon with the measuring tape or place a length of string around the balloon and measure the string with a meter stick.
4. Let each student record these measurements and mark their balloons with their names, and put them away for the next day (they could be placed in cupboards or stuck to the walls).
5. The next day, have students measure the diameter and length of their balloons and compare these measurements with those of the day before.

**What questions to ask:**

1. What made the balloon shrink in size?
2. Which of the three groups (sizes) had the fastest shrinking balloon (was shrinking fastest) ?
3. Were there any leaks in the balloons?
4. What would the balloon do if kept for another day?
5. Where do we find a applications of this principle in daily life?

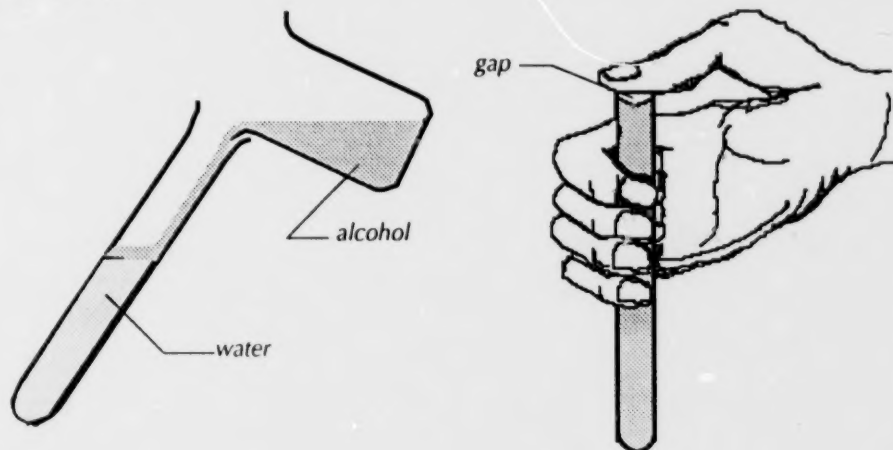
**How to explain it:**

The **air molecules** in the balloon are much smaller in size than the **rubber molecules** of the balloon itself. Although many layers of rubber molecules are contained in the balloon membrane, the tiny air molecules can slowly **slip through** these bigger ones that hold them inside the balloon. As the pressure inside is larger than outside, the air molecules move faster inside and push through the rubber. Over time, so many air molecules **diffuse** through the rubber that the **pressure inside decreases**, thus decreasing the size of the balloon. The rate of losing air molecules is greater for the larger balloon, because of the higher pressure.

## 1.4.03. THE SHRINKING MIXTURE OF LIQUIDS

**What you need:**

1. A test tube and small beaker/cup.
2. Alcohol, - ethyl-, methyl-, or isopropyl-alcohol (methyl hydrate or rubbing alcohol, or ditto fluid may be used).

**How to do it:**

1. Fill the test tube half way with water.
2. Hold this test tube slanted and pour the alcohol slowly from a beaker/cup until brim full.
3. Hold the test tube vertically and place your thumb on the mouth of the tube, making sure that no air bubble is trapped.
4. Show the students that the tube is completely full (no bubble under the thumb).
5. Invert the tube several times (keep thumb on opening of test tube at all times; do not release the pressure).
6. Show to students that now the liquid level is lowered and that there is a bubble in the tube.

**What questions to ask:**

1. Did the alcohol or water evaporate?
2. Was there any liquid spilled by inverting the tube?
3. Did the liquid shrink or contract?
4. Was there space between the water and alcohol molecules?

**How to explain it:**

By closing the opening of the test tube tightly with the thumb, and not taking it off while inverting, no evaporation or spilling of the liquid could occur. By inverting the test tube, mixing of water and alcohol takes place, and because there are **spaces between the molecules**, the alcohol molecules slip in between the water molecules, thus making the total volume of the mixture become less. Although the spaces between the molecules cannot be seen by the naked eye, this demonstration shows that there must be room between the molecules. If ethyl alcohol is not available, methyl-hydrate (methyl alcohol) or rubbing alcohol (isopropyl alcohol) can be easily obtained from a drug store, and may replace it.

Examples of this characteristic of molecules can be found in bicycle or car tires, which need to be pumped once a while, because air molecules have been **diffusing** through the tires.

1.4.04. **IS THE CONTAINER LEAKING ?**

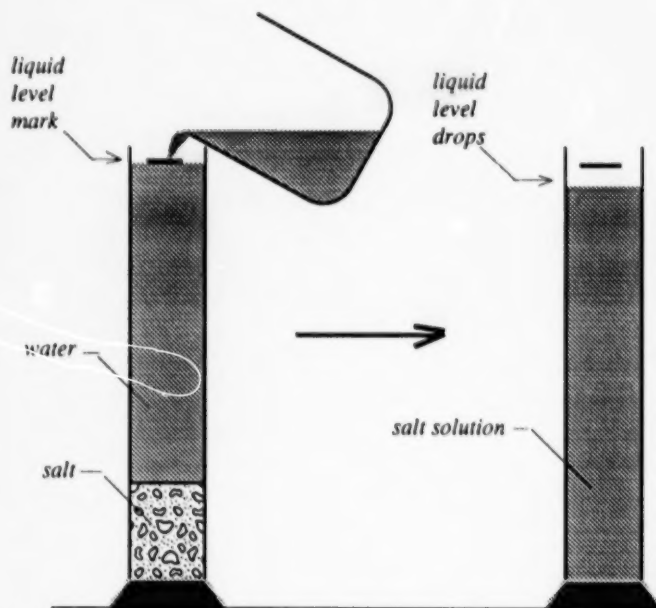
- Materials:**
1. Water softener salt pellets or table salt.
  2. A graduated cylinder and a beaker/cup.

**Procedure:**

1. Fill the cylinder 1/3 full with water softener salt pellets or with table salt.
2. Add water until full and mark the liquid level with a grease pencil or tape or rubber band.
3. Let it stand for a few minutes and observe the liquid level.

**Questions:**

1. Where did the water go?
2. Is the cylinder leaking any water?
3. What do the salt molecules do when they dissolve?
4. Can we use other salts to do this demonstration?
5. Can sugar be used to do this same demonstration?



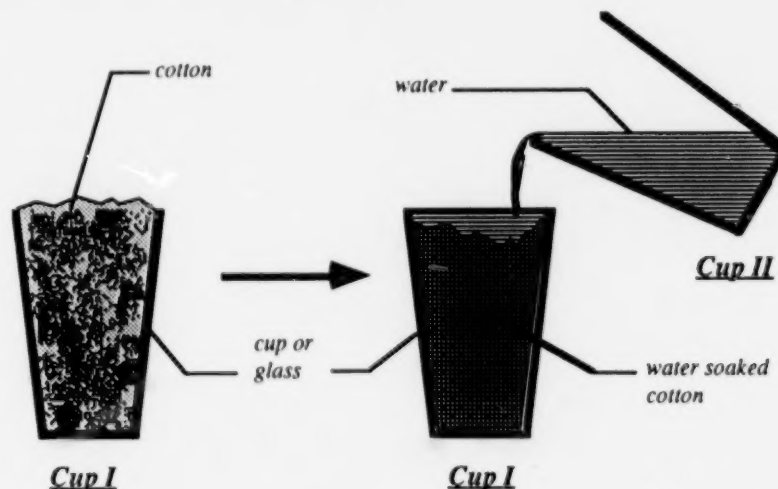
**Explanation:**

Students might incorrectly infer that the water is absorbed by the salt. As a follow-up to a response like this you might pour out the water before all the salt is dissolved and re-fill it with fresh water: the water level will drop again! The main cause of the water level dropping is, that the **salt molecules** break down into **ions**:  $\text{NaCl}$  molecules into  $\text{Na}^+$  and  $\text{Cl}^-$  ions, which are much smaller than the molecules, and these ions can slip in between the water molecules. This makes the total volume decrease.

Other salts that dissolve in water will exhibit the same property. Most inorganic water-soluble salts will do this. The sugar molecule is large in size and does not ionize when dissolved in water, so that the water level will stay at about the same spot when sugar is used. This demonstration shows students that there are **spaces in existence between water molecules** that are not detected by the naked eye.

1.4.05. **IS THE CUP REALLY FULL ?**

- What you need:**
1. Two clear plastic cups (or drinking glasses)
  2. Absorbent cotton balls (or new Pampers diapers)



**How to do it:**

1. Fill one of the cups full with cotton balls (or the inside of the Pampers diapers) and fill the other cup almost full with water.
2. Ask the students: "Do you think I can pour all this water in the cotton-filled cup without letting it overflow (anticipated answer: "No way!")"
3. Then proceed to pour all the water slowly into cup No.1 without letting one drop overflow!

**What questions to ask:**

1. Why did the water not overflow?
2. How much space did the cotton actually take in the cup?
3. What was the shape of the water meniscus in cup I?
4. How much additional water can be added to the full cup?
5. Would this same demonstration work with oil? Alcohol? Other liquids? Non-absorbent cotton?

**How to explain it:**

When compressed, the cotton would most likely take very little space. Besides, the cotton is **water absorbent**, which means that the water molecules can come very close to the cotton molecules, and thus they can slip into each other. Because of these characteristics of the cotton and the *space that exists between the water molecules*, the water can **all** be poured into Cup I without overflowing. The material inside a Pampers diaper is **polyacrylate**, and is so absorbent that the water is actually bound by the chemical. The mixture turns into a gel and the water cannot be poured out anymore.

This polyacrylate powder is so water absorbent that it can hold 400 times its weight in water. An intriguing demonstration is to pour water in an opaque cup holding some polyacrylate powder (which will turn into a gel), and by turning this cup upside down no water pours out!

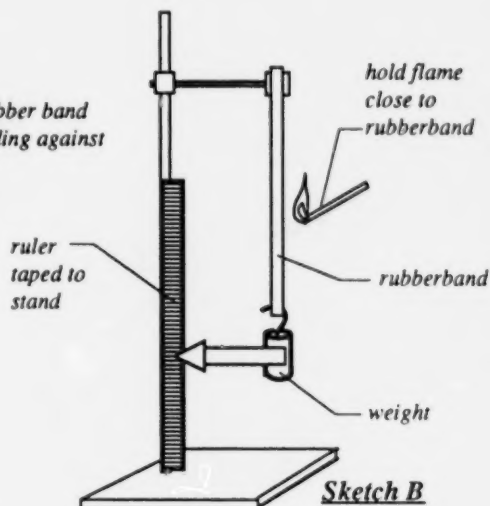
The water disappeared!

1.4.06. **THE COOLING RUBBER BAND**

**What you need:** 1. A wide rubber band, match and ruler.  
2. A stand and a 100 gram weight.



Sketch A



Sketch B

**How to do it:**

1. Hold the rubber band partly stretched between your forefingers, such that the band touches your upper lip.
2. While the rubber band touches your lip, stretch the band fully and release the tension slowly. What do you feel? (See Sketch A).
3. Hang the rubber band from a stand and hook a 100 gram weight to the band (tape a paper arrow to the weight pointing to the vertical ruler (see Sketch B).
4. Note the position of the paper arrow.
5. Now strike a match and hold the flame close to the rubber band. Observe the position (reading) of the paper arrow.

**What questions to ask:**

1. How did the rubber band feel (against the upper lip) when it was stretched? When the tension was released?
2. What would stretching of the rubber do to the rubber molecules?
3. What did the rubber band do in demonstration B, when the flame was held near to it?
4. What do metals and other materials generally do when heated?
5. What other material behave the same way as rubber when heated?

**How to explain it:**

Rubber is a **high polymer**, which means that it consists of large molecules (a chain of repeating molecules) with many side branches. When stretched these molecules bump and slide against each other, creating heat. This makes the rubber band feel warm against the upper lip. When the tension is released, the molecules can relax back into their normal positions and cooling takes place in the rubber. This cooling process in the rubber means that it is withdrawing heat from its environment. In demonstration B, this heat is supplied by the environment and forces the rubber band to contract. Other materials that are composed of polymers behave similarly, like: polyethylene, polystyrene, and other plastics.

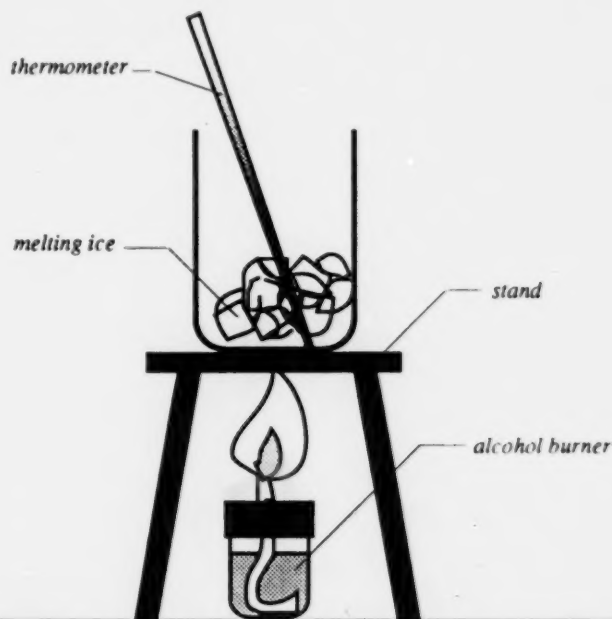


1.4.07. **THE VANISHING ICE CUBES**

- What you need:**
1. A bag of ice cubes (3-4 cubes per pair of students).
  2. A thermometer, beaker, alcohol burner and stand (for each pair).
  3. Graph paper for all students.

**How to do it:**

1. Distribute the materials to the students and have them work in pairs.
2. Have one student stir the ice-water mixture and another one observe the temperature every minute while it is being heated (a third student may record the temperature called out).
3. After all the ice is melted, have the students keep on heating the water and record the temperature every minute until the water boils for about ten minutes.
4. Have the students plot the observed temperatures (Y axis) against the time (X axis) on a graph.



**What questions to ask:**

1. What was the temperature doing while there was still ice present?
2. Where did the heat from the alcohol flame go during that time?
3. What did the temperature do while the water was boiling?
4. Where did the heat from the flame go during this boiling time?
5. What will eventually be left over if the boiling was continued?
6. When heat is not added to the melting process, what will the melting ice do to the environment?
7. When heat is not added to the evaporating process, what will water that is evaporating do to the environment?

**How to explain it:**

In the beginning of the heating process, the **heat was used to melt the ice**. This is why the temperature stayed on  $0^{\circ}\text{C}$ . This remains at that temperature as long as there is still ice present. As soon as all the ice is melted, the temperature rises steadily till  $100^{\circ}\text{C}$ , then it levels off and stays at the boiling temperature until all the water is evaporated (this temperature may be close to  $98^{\circ}\text{C}$  depending on the elevation of the place). The heat during the boiling process is used to transfer the liquid into the vapor state.

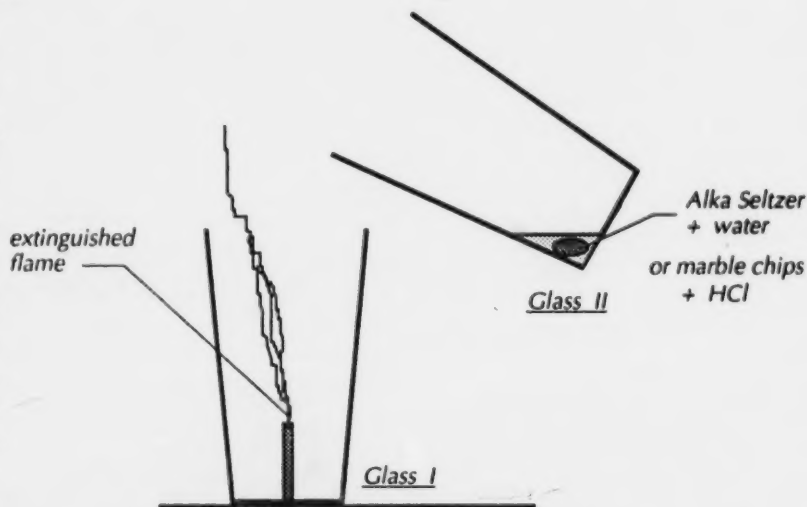
1.4.08.

**THE INVISIBLE FLAME EXTINGUISHER**

- What you need:**
1. Two beakers (300 ml) (transparent plastic cups will do).
  2. Marble chips and hydrochloric acid (HCl) or Alka Seltzer tablets & water.
  3. A candle and matches.

**How to do it:**

1. Secure the candle in the center of one of the beakers/cups.
2. Put a teaspoonful of marble chips (calcium carbonate) in the other beaker and pour a few drops of dilute HCl on it, or use a little water plus 2 tablets of Alka Seltzer (cover it with a 5x8 card for a few seconds).
3. Light the candle in the first beaker and pour the gas that has developed in the second beaker into the first (see Sketch-do as if you were pouring liquid): the flame will be extinguished.
4. To repeat the lighting of the candle, the air has to be replenished by inverting the beaker and holding it upside down for a while, then the candle can be lit and the gas poured to extinguish it again.



**What questions to ask:**

1. What was it that extinguished the candle flame?
2. What gas was formed in the second beaker?
3. Could we observe the gas pouring down into the first beaker?
4. Why does the first beaker have to be inverted before relighting and extinguishing it for the second time?
5. What are other invisible gases that you can name?

**How to explain it:**

The gas formed in the second beaker is **carbon dioxide**. By adding dilute hydrochloric acid to marble chips, we get the following reaction:  $2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$ . The same gas is formed when Alka Seltzer (mostly sodium bicarbonate) is plunked into water. Carbon dioxide is an invisible gas, which is heavier than air, and which has the property of extinguishing flames. The fact that it is heavier than air makes it possible to pour the gas from one container into the other. This is also why it is necessary to invert the first container to replenish the air before trying to light and extinguish the flame for the second time.

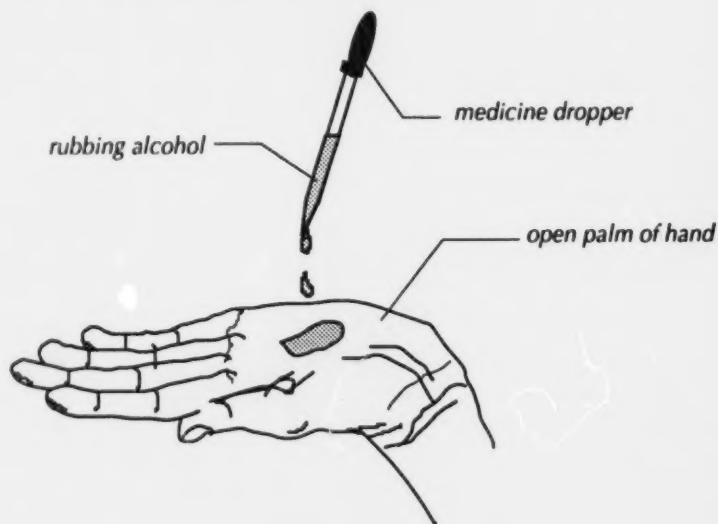
Carbon dioxide gas is used in actual fire extinguishers. The gas is compressed until it becomes a liquid and this liquid is put in steel cylinders. When opening the valve of the cylinder, carbon dioxide gas is released and can be used to put out oil fires especially.

1.4.09. **THE DISAPPEARING LIQUID**

- What you need:**
1. A medicine dropper & wall clock or watches.
  2. Rubbing alcohol (isopropyl alcohol) or methyl hydrate (methyl alcohol).

**How to do it:**

1. Have each of the students stretch out one of their hands with the palm facing up and held horizontally.
2. Come around with the 'colorless liquid' and the dropper; place 3-4 drops on each of the palms.
3. Have the students measure the time it takes for the liquid to evaporate completely.
4. You may repeat the activity, but this time have the students race to evaporate the liquid as fast as possible. They may do everything to the liquid except removing it from the palm or applying a match to it (**definitely not!**). Some may try blowing, spreading it, etc.



**What questions to ask:**

1. Where did the liquid disappear to?
2. What did you observe during the evaporation process?
3. How long did it take for three drops to evaporate?
4. Which method proved to be most effective to speed up evaporation?
5. Where did the energy to change the liquid into a gas come from?

**How to explain it:**

As alcohol is very **volatile**, it **evaporates** quickly. The three drops on the palm evaporate within a few minutes. The transfer of a liquid into its vapor state takes energy. This energy is usually supplied to the liquid in the form of heat. When this heat is not supplied to the liquid, and it evaporates by itself, it withdraws the heat from its environment. This is why the palm feels cool.

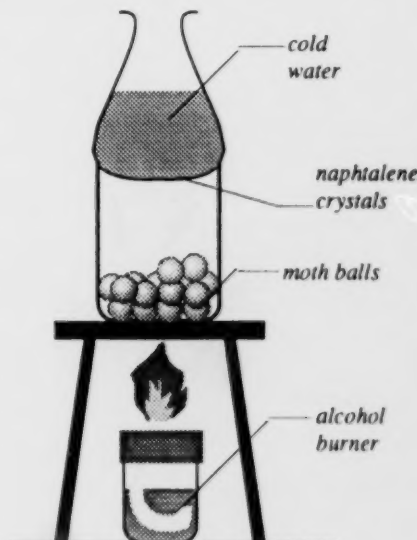
The evaporation process can be speeded up by blowing over the liquid, making the surface area larger by spreading it over the whole palm; doing both at the same time would probably be most efficient. Blowing warm air over the liquid would most likely increase the rate of evaporation.

1.4.10. CHANGING GAS INTO CRYSTALS

- What you need:**
1. A medium size beaker/a heat-resistant glass jar/ metal can.
  2. Erlenmeyer flask or glass jar with a larger base than beaker No. 1 or the can.
  3. Alcohol burner and stand or a stove top, moth balls/naphthalene flakes.

**How to do it:**

1. Place 4 or 5 moth balls or a scoop of naphthalene flakes in the beaker or metal can and heat it slowly over a small flame or the stove.
2. Fill the flask/jar half way with cold water and stack the flask/jar on top of the beaker/can holding the moth balls (see sketch).
3. Leave the alcohol burner/stove on until all the moth balls are melted, then blow the flame out / switch the stove off and leave the flask/jar on top of the beaker/can for another 5-10 minutes. (A longer time is even better.)
4. Lift the flask/jar carefully and slant the bottom towards the students to show the crystals.

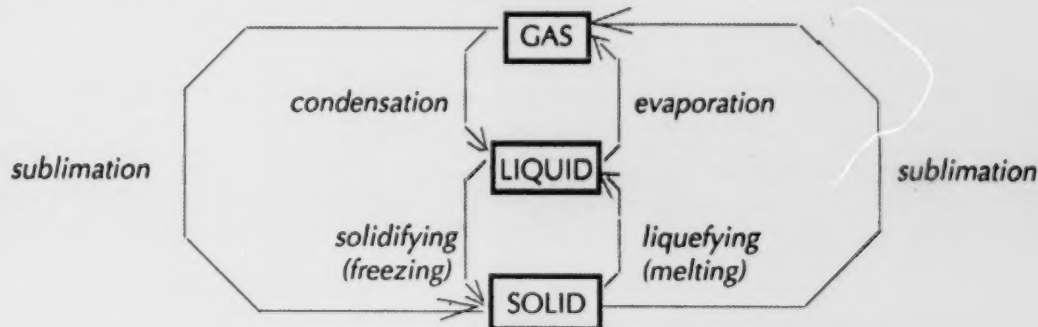


**What questions to ask:**

1. What is the process of changing solid into liquid called?
2. What is the process of changing solid into gas called?
3. What is the process of changing gas into solid called?
4. Where does the changing of solid into gas occur in daily life?
5. What purpose does the cold water have in the flask/jar?
6. What other material behave like the moth balls when heated?

**How to explain it:**

By heating the moth balls, they change from solid into liquid state and also into the gaseous state directly. This first process is called **melting** or **liquefying** and the second is **sublimation**. Other processes are named in the following scheme:

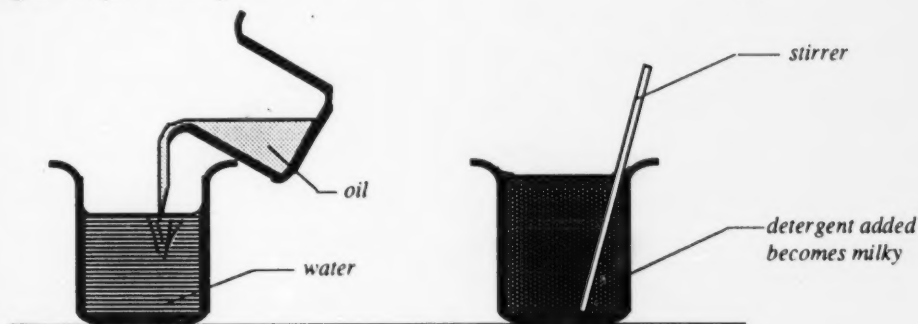


Other materials that sublime are sulfur (found in volcano craters), iodine, and ice.



1.4.11. **MAKE MILK FROM WATER AND OIL**

**What you need:** 1. A glass/plastic clear jar (or beaker), stirrer.  
2. Cooking oil, liquid detergent.



**How to do it:**

1. Fill the jar about half full with water and pour half of that volume (1/4 of the jar volume) of oil over the water.
2. Stir the two liquids with a spoon or glass stirrer and leave it for a while, and observe what is happening to the mixture.
3. Ask the students: "How can I make the two liquids stay mixed?" Now add a few squirts of liquid detergent and stir thoroughly.
4. After mixing thoroughly, leave the jar alone and observe (if the emulsion separates again you may need more detergent or more vigorous stirring or both).

**What questions to ask:**

1. After stirring without detergent, what did you observe in the jar?
2. What made the two liquids stay mixed as an emulsion?
3. How would you define "emulsion"?
4. What is the term for a finely divided solid in a liquid?
5. Can you name some examples of finely divided solids in a liquid?
6. What is a finely divided solid in a gas? Examples?
7. What do we usually call fine droplets of liquid in the air?
8. What do we call finely divided gas bubbles in liquid?

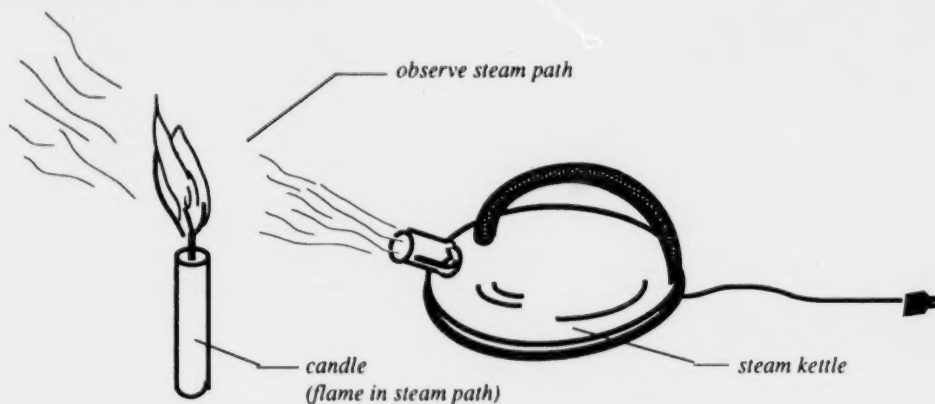
**How to explain it:**

When mixing oil and water, the oil will break up in small droplets and be dispersed in the water very temporarily. After leaving the jar with the mixture alone for a while, the two clear liquids will separate: oil forming a layer above the water because of its smaller density. After adding some liquid detergent (the **emulsifier**) and some vigorous stirring, the small droplets of oil will stay dispersed forming an **emulsion**. Examples of an emulsion: milk, mayonnaise, salad dressings, butter, etc. Finely divided droplets of liquid in gas is **mist or fog**, colloidal solid in liquid is called a **suspension**: muddy water; a solid colloid in gas is called **smoke**. An example of a colloidal dispersion of solid in solid is gold particles in ruby glass; gas bubbles in liquid is commonly called: **foam**.



1.4.12. **THE INVISIBLE STEAM**

- What you need:**
1. An ordinary steam kettle (for boiling water).
  2. A large candle or an alcohol burner.



**How to do it:**

1. Boil some water in the kettle.
2. As soon as the water boils, observe the steam leaving the kettle spout.
3. Light the candle/alcohol burner and place the flame slightly under the path of the steam. What do you observe?
4. Move the burning candle/alcohol burner to another spot in the steam path; what do you observe about the steam?

**What questions to ask:**

1. Did you observe any steam above the burning candle flame?
2. What makes steam visible to the human eye?
3. How is fog formed in the atmosphere?
4. Does cold or warm air contain more moisture?
5. Why are clouds mostly formed at higher elevations?
6. What are conditions for fog to form?

**How to explain it:**

The steam is not visible in hot or warm air, because steam can only be seen when it is in the form of **tiny condensed droplets**. These droplets turn into vapor at higher temperatures. Fog and clouds are only formed when the atmosphere contains a lot of moisture and when the temperature is so low that the water vapor condenses. These lower temperatures are present usually at higher elevations.

Moisture comes in the atmosphere from the soil, from plants, even from the breath that humans and animals exhale, but mostly from the ocean. Try exhaling against a mirror and you will see condensation of vapor.

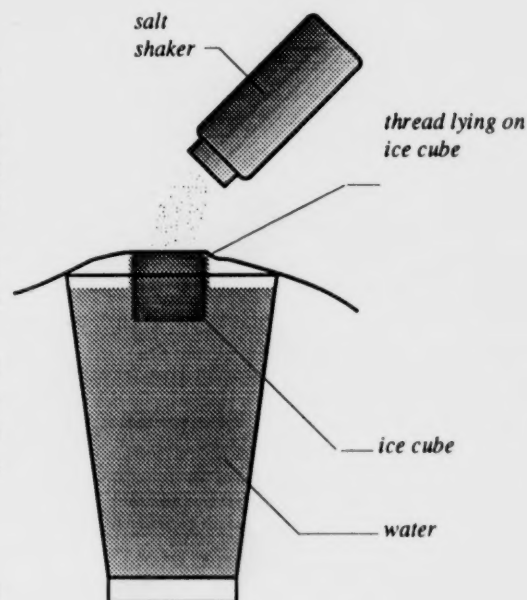
Hot air can contain much more water vapor than cold air. When the atmosphere is **saturated with moisture**, the decreasing of the temperature will precipitate out excess moisture. This precipitate is in the form of fog or rain or snow, depending on how low the temperature is.

1.4.13. **LIFT AN ICE CUBE WITH SALT**

**What you need:** 1. An ice cube floating in cold water in a cup.  
2. A sewing thread and salt shaker.

**How to do it:**

1. Let an ice cube float in a full cup with cold water.
2. Show students the salt shaker and the thread and ask: "How can I lift the ice cube out of the water without getting under the cube?"
3. Let the thread lie on the ice cube and sprinkle salt on it—especially close to the thread.
4. Wait a minute or so, lift the thread slowly to check whether the water above it has frozen; if so, lift both ends of the thread and lift the ice cube out of the water.



**What questions to ask:**

1. What does salt do to ice on the road in the winter time?
2. At what temperature does ice melt?
3. What do you think salt does to the melting point of ice?
4. What must the melted ice above the string do in order to lift the cube?
5. Where else do we find this principle of lowering the melting point of ice applied in daily life?

**How to explain it:**

As salt water has a lower **melting** or **freezing point** than pure water, the addition of salt to the ice cube makes it melt at the places where the salt is sprinkled. This means that the ice around the thread will melt, but the temperature of this water above the ice cube is still below  $0^{\circ}\text{C}$ . When the salt dissolves in more of the melted ice, the solution gets more dilute, increasing the freezing point close to  $0^{\circ}\text{C}$ . As this water still has a temperature of a few degrees below  $0^{\circ}\text{C}$ , it freezes again. This makes it possible to lift the ice cube out of the water.

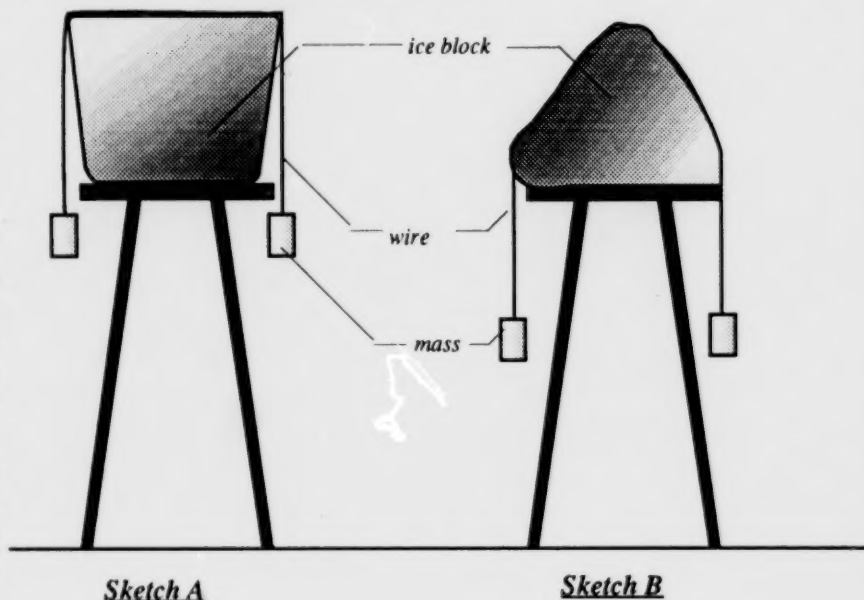
When making ice cream at home, crushed ice and salt are mixed in the mantle of the ice cream maker to lower the temperature below the freezing point of water. This lower temperature will make the ice cream mixture freeze. If the mixture was not stirred, a solid ice block would be the result of the freezing, but since the mixture is constantly stirred, it is kept soft and it is turned into ice cream.

1.4.14. **CUT THROUGH ICE WITH A WIRE**

- What you need:**
1. A rather large ice block.
  2. An iron or copper wire (about 1 m/3 ft long).
  3. Two 1 Kg/2 lbs weights or large rocks, tripod or tall tin can.

**How to do it:**

1. Place the ice block on the stand or on a tall tin can such that the ice block overhangs the edge of the can (the ice block should be larger in diameter than the can or tripod).
2. Tie the wire ends to the weights and hang it over the ice block, such that the weights are hanging freely (see Sketch).
3. Leave the wire hanging for a while and observe the top part of the ice block on which the wire rests (hang heavier weights on the wire to speed up the process).



**What questions to ask:**

1. Why does the wire cut into the ice?
2. What happened to the water above the wire?
3. What property is being lowered by increasing the temperature?
4. Would a smaller ice block be cut faster?
5. Would larger weights cut the ice block faster?
6. Will the wire cut faster through block A or B? (See Sketch)

**How to explain it:**

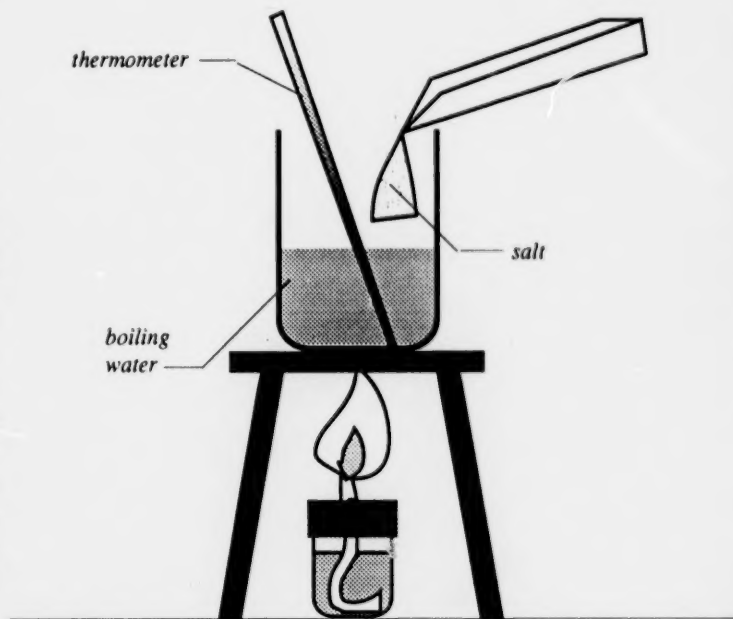
Under high pressure the **melting point** of solids gets lowered. Under the wire, the ice molecules are pressed and thus they move faster. Immediately under the wire then, we get faster moving molecules, thus higher temperatures and melting of the ice occurs. The wire moves through this water, but as soon as that water gets above the wire, the pressure is off and the temperature of the water gets below  $0^{\circ}\text{C}$  and it freezes again. The larger the weights, the higher the pressure on the ice, and thus the faster the temperature under the wire is raised. This increases the rate at which the wire cuts through the ice. The same thing happens when the size of the ice block or the surface area between the wire and the ice is reduced (Sketch A).

1.4.15. **HEAT WATER ABOVE THE BOILING POINT**

- What you need:**
1. A small beaker (100 ml)/heat resistant cup or small pan & thermometer.
  2. A burner and stand or stove top.
  3. Table salt (sodium chloride).

**How to do it:**

1. Let students work in pairs. Distribute the above materials to each pair of students.
2. Heat about 20 ml of water, place the thermometer in the beaker/pan and record the temperature every half minute (one student stirs with the thermometer and reads off the temperature while the other records it).
3. As soon as the water boils, let students add different amounts of salt to the water (2, 4, and 6 g of salt could be given to three groups of student pairs).
4. Continue heating, stirring, observing the temperature, and recording it very half minute until the water boils again.



**What questions to ask:**

1. What happened to the boiling when the salt was added?
2. What happened to the temperature after the salt was added?
3. What is the normal boiling point of water?
4. Which of the three groups had the highest boiling point?

**How to explain it:**

As soon as the salt is added to the boiling water, the temperature drops and the water stops boiling. This is because the salt has a lower temperature and dissolving it in the water absorbed some of the heat. With the salt in the water, the water molecules adhere not only to each other—**adhesion**, but also to the **salt ions**, which makes it harder to transfer the water into the gaseous state. This is why the water has to have a higher temperature to boil. The more salt, the higher the boiling temperature of the solution, but the temperature of the water vapor stays at 100° C (this can be checked by lifting the thermometer above the liquid).

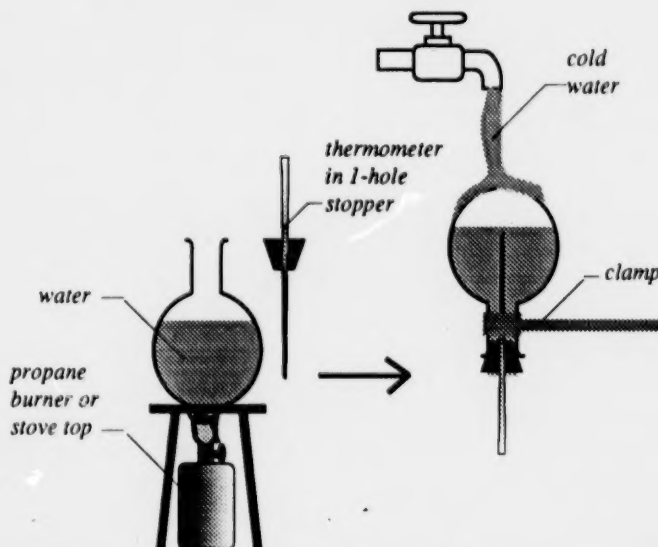
This demonstration shows that impure water (water that contains minerals and salts) has a higher boiling point than pure (distilled) water.

1.4.16. **BOIL WATER WITH COLD WATER**

- What you need:**
1. A round or flat bottom flask, clamp, boiling chips.
  2. A one-hole stopper & thermometer fitting in the flask.
  3. A burner & stand/stove top.

**How to do it:**

1. Fill the flask 3/4 full with water, put a few boiling chips in it, and heat over the burner and let stand until boiling (boiling chips can be made from a broken china cup by crushing).
2. Attach clamp on flask's neck, shut flame off and immediately close flask with the one-hole stopper with the thermometer in it, and have a student read off the temperature (should be about 98°-100° C).
3. Invert the flask and hold it under a cold stream of water from the tap above a sink, or wipe the bottom of the flask with a towel soaked in cold water.
4. Observe boiling water and have students read off the temperature.



**What questions to ask:**

1. Why does the water stop boiling after the heat is taken away?
2. At what temperature does water boil at normal pressure?
3. What is the cold water doing to the water vapor in the flask?
4. What do you think the pressure above the water in the cooled flask is?
5. What is the lowest temperature at which the water is still able to boil in the cooled flask?

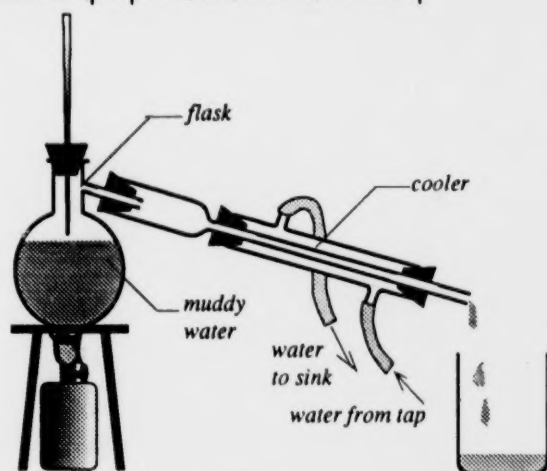
**How to explain it:**

By boiling the water (the purpose of the boiling chips is to obtain an even boiling), **steam** is formed and this **replaces** almost all the **air** above the water in the flask. By closing it off immediately after boiling point is reached with the stopper and the thermometer, the air is trapped out of the flask. When the flask is cooled off with the cold water, the water vapor above the water condenses on the colder surface and a **partial vacuum** above the water is created. This makes the water boil at much lower temperatures than the normal boiling point of 100° C, because the water molecules can jump out of the liquid state much easier into the gaseous state. **Normal** indicates the boiling point at **normal pressure** which is 760 mm mercury or the barometric pressure at sea level (one atmosphere).

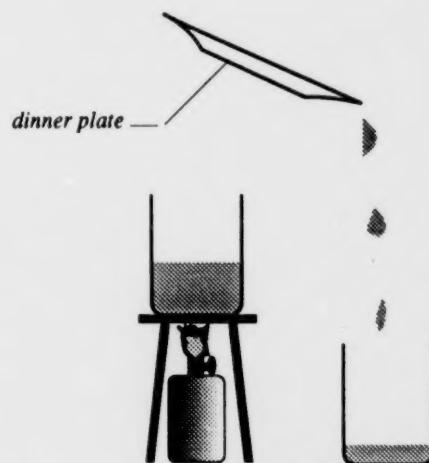


1.4.17. DRINK MUDDY WATER

- What you need:**
1. Distillation apparatus (flask, thermometer, cooler) (if not available revert to point 2).
  2. Two beakers (200 ml) and a dinner plate.
  3. Burner (propane) and stand/stove top.



Sketch A



Sketch B

**How to do it:**

1. Set the distillation apparatus up as in Sketch A. Place some muddy water in the flask and start heating it. (If the distillation apparatus is not available, proceed with the following points).
2. Place one beaker (heat resistant) on the stand and burner/stove top, and fill it with some muddy water. Start heating this.
3. As soon as it starts to boil, hold a large dinner plate somewhat slanted above the beaker (in the steam) and let the condensed water drip into the other beaker (see Sketch B).

**What questions to ask:**

1. At what temperature does water boil at normal pressure?
2. What temperature do you think would the boiling muddy water have?
3. Why do the impurities stay back in the flask (or 1st beaker)?
4. What is the purpose of the cooler (or dinner plate)?
5. What would be another way to purify the muddy water?
6. Would rain water be the same as distilled water?

**How to explain it:**

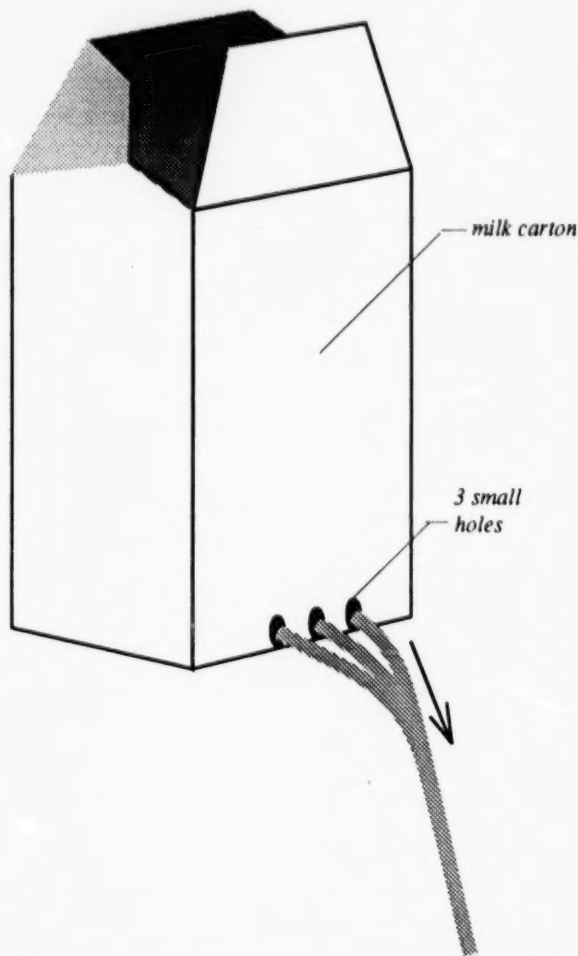
The muddy water in the flask or first beaker would most likely reach a temperature above 100° C before it starts to boil, because of the impurities in the water. The thermometer, however, would indicate the **boiling temperature** of pure water, which would be a little below or close to 100° Celsius, depending on the elevation of the place. The impurities stay back in the flask, because it is only the water molecules that jump out of the liquid state into the vapor state, which are condensed back into the liquid state by the cooler or the cool plate. Another way of purifying water for cooler drinking would be to filter it through a thick layer of sand, although it would contain minerals, which distilled water would not. Rain water would pick up dust and chemicals in the air (especially in polluted areas).

1.4.18. THE CLINGING WATER STREAMS

**What you need:** 1. An empty milk carton or tin can.

**How to do it:**

1. Make three small holes in one of the sides near the bottom of the milk carton—about 1/2 cm or 1/8 inch away from each other.
2. Fill the carton full with water and observe the water streams coming out of the holes.
3. Bring the streams together with the fingers to make it one big stream. Separate the streams by pushing one finger through the middle of the large stream (usually it requires several tries to separate them).



**What questions to ask:**

1. Why does the water stay in one stream once they are brought together?
2. How far can the holes be placed apart for the water still to be able to cling together?
3. Is it easier to separate (or bring together) the streams with a full or almost empty carton?

**How to explain it:**

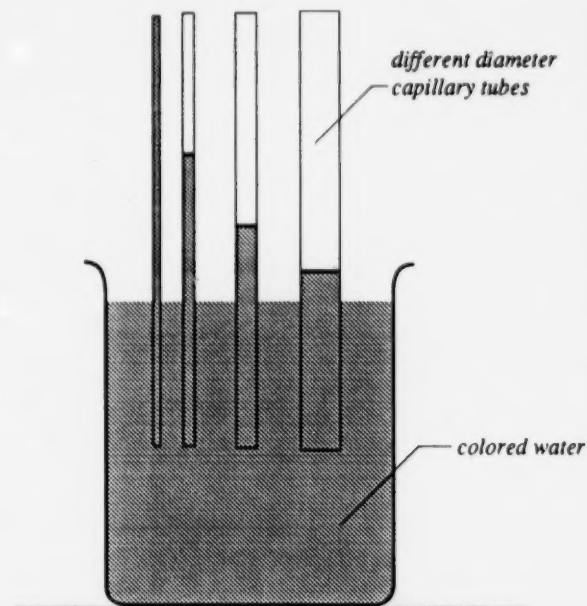
The closer the holes are placed in the carton, the easier to get a whole stream out of the carton, but the harder to separate it into three separate streams. The farther the holes are, the harder to bring the separate streams together. It is the **cohesive forces** between the water molecules that keep the streams together. The fuller the carton, the larger the pressure, and the easier the separate streams are obtained. With less water in the carton, we will get lower water pressure and thus an easier cohesive whole stream. We find this phenomenon in daily life in the shower head with the many holes in it. When the valve is turned wide open, separate streams are distinguished, but when the valve is only partially opened, the many small streams will cling together and form one whole stream.

1.4.19. **THE SMALLER, THE STRONGER**

- What you need:**
1. Three or four capillary tubes of different diameter.
  2. A small beaker/cup & food coloring.

**How to do it:**

1. Fill the beaker with water and place a few drops of food coloring in it.
2. Hold the three or four capillaries close to each other and dip them in the water; observe the water level in each of the capillaries.
3. When a flat cell is available, the capillaries can be projected on the screen by slanting the overhead projector slightly.



**What questions to ask:**

1. Will the water level in the capillaries change when the tubes are either moved higher or lower in the beaker?
2. What makes the water go up in the tubes in the first place?
3. Why does the water move up higher in the narrower capillary?
4. Where do we find an application of this capillary action in daily life?
5. What is the attraction force between unlike or like molecules of matter called?

**How to explain it:**

When a capillary tube is dipped in water, the **adhesive forces** between the water and the glass of the tube are so large that the water is pulled upwards. The smaller the capillary, the more glass surface per unit number of water molecules exists, and thus the larger the adhesive force. Furthermore, the distance between the water molecules and the glass molecules is so much shorter in the narrower tube, that the **adhesive attraction between these unlike molecules** is greatly increased.

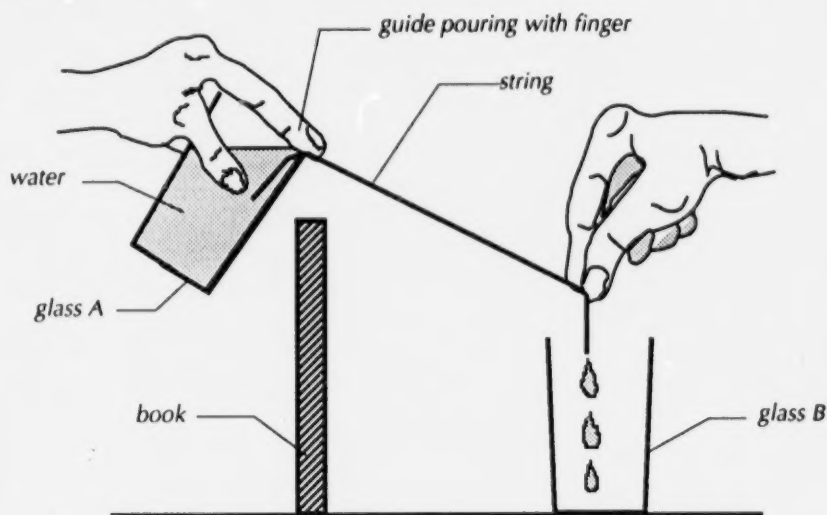
This is how the fibers in plants and trees bring up the water from deep in the ground to high up in the leaves. **Capillary action** combined with **osmotic pressure** caused by the **semi-permeable** walls of the fibers and the plant juices, push up the water to the tree top. Another example of adhesion is the application of paint on any surface. The paint clings to the surface because of the adhesive forces between the paint and the surface molecules.

1.4.20. **POUR WATER ALONG A STRING**

**What you need:** 1. Two beakers or plastic cups.  
2. A water-absorbent string (thin rope).

**How to do it:**

1. Fill one of the beakers about 3/4 full with water.
2. Stand a book about 20 cm away from the empty beaker.
3. Show students the string and ask: "How can I transfer the water from beaker A to B without moving beaker A over or around the book?"
4. Wet the string thoroughly in the water.
5. Hold one end of the string in beaker A and the other end over beaker B (see Sketch) and pour the water slowly along the string. (Make sure to hold the string taut).



**What questions to ask:**

1. Why was it necessary for the string to be wet?
2. What forces were holding the water to the string?
3. What other materials can be used in place of the string?
4. Is it possible to pour other liquids along a string?

**How to explain it:**

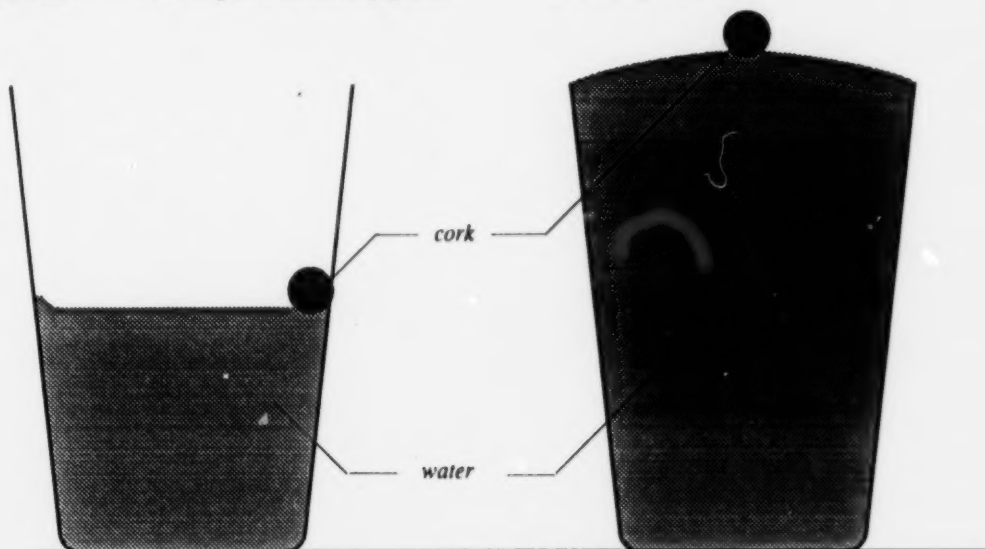
The string needs to be wetted so that water molecules would **adhere** to the molecules of the string. The water molecules are attracted to the string molecules by **adhesion**. Once the string is wet, the water can cling to the already present water molecules, because of the **cohesive** forces between like molecules of water. The transfer of water will not succeed with a dry string or any material which is not water absorbent.

Other materials that would have the same properties as the water-absorbent string would do the same job, like: cotton, cloth, paper, wood, etc. Materials that are not water-absorbent, like nylon or wool cannot be used for this purpose.

Liquids that have strong cohesive forces between their molecules, like oil, vinegar, syrup, etc. can be poured along a string as well, provided that we make sure that the string or whatever material is used to transfer the liquid can absorb it.

1.4.21. **WHERE DOES THE CORK FLOAT?**

What you need: 1. A regular drinking glass. 2. A small cork.



How to do it:

1. Fill the glass half way with water and float the cork on the water surface: observe!
2. Where does the cork float? (It should be attracted toward the side of the glass; move it somewhat if it stays in the middle.)
3. Now add more water to the glass and fill it brimful. Observe where the cork now floats.
4. Try to push the cork towards the edge: it will not stay there!

What questions to ask:

1. Why is the cork moving towards and sticking to the side of the glass (with the glass half-filled)?
2. Where is the water level highest in the half-filled glass?
3. Why is the cork floating in the center of the full glass?
4. Where is the water level highest in the full glass?
5. Why can we fill the glass more than full without overflowing the water?

How to explain it:

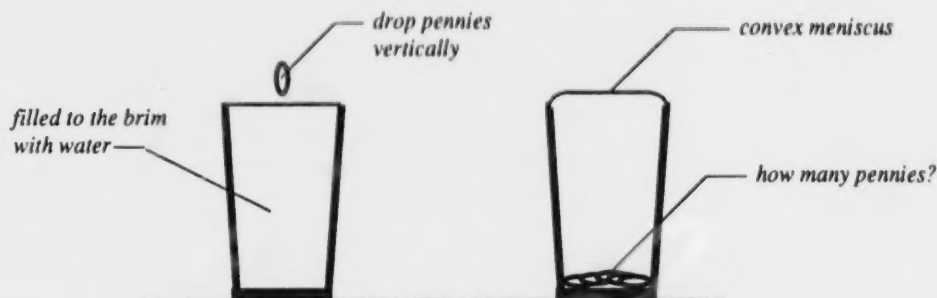
When the glass is half-filled with water, the circumference of the **meniscus** is the highest level. The shape of the meniscus or water surface is **concave**. This is caused by the **adhesive forces** between the water and the glass molecules. As a result of this high level at the side of the glass, the cork moves to that place.

When the glass is brimful filled with water, the surface tension and the **cohesive forces** between the water molecules form a film on the surface of the water, making it possible to fill the glass more than full. The highest level of the meniscus is now in the center of the glass (the shape of the meniscus is now **convex**), which is where the cork will float. As floating objects tend to float at the highest spots of the meniscus, the center would be the spot where the cork would float when the glass is full.



1.4.22. **HOW MANY PENNIES CAN GO IN ?**

**What you need:** 1. Two regular drinking glasses, liquid detergent.  
2. About 50 pennies (or other small coins).



**How to do it:**

1. Make sure that the drink glasses are very clean and dry. Place one on the table and fill it to the brim (not too overflowing full, just full).
2. Now ask the students: "How many pennies can I put in the glass before it overflows?" Anticipated answer: "5, 10, 15, even 20 maybe".
3. Start putting the pennies in the glass of water, very carefully with its edge in first (vertically), and let the students count.
4. Surprised at the result? Now place the other glass on the table, in which you put a drop of detergent beforehand (without the students noticing it), and also fill this to the brim with water.
5. Now ask a student to put just as many pennies in this glass. What happened here?

**What questions to ask:**

1. How many pennies could go in the first glass? In the second?
2. What made the water overflow so easily in the second glass?
3. What kept the water from overflowing in the first glass?
4. What shape did the meniscus take form in the first glass?
5. How would the number of coins compare if we used dimes instead of pennies? Nickels instead of pennies?

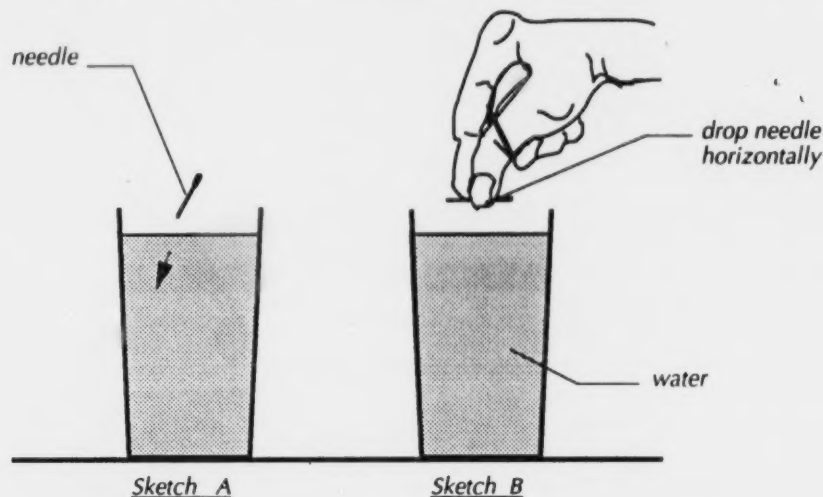
**How to explain it:**

It is possible to put close to 50 pennies in the full glass of water, depending on how full the glass was filled. A thick-rimmed glass will look full even when the meniscus is a little below the rim. Then it is possible to put many more pennies in. A larger glass also increases the number of pennies that can be dropped. The water forms a **convex meniscus** due to the **surface tension**, which is nothing but a manifestation of **cohesion** of the surface molecules.

In the second glass, where detergent was present, this surface tension is broken. The cohesion between the surface water molecules is much smaller, and thus the water overflows much sooner. (Another way of inconspicuously putting detergent in the second glass, is wetting the second bunch of pennies with a little detergent before giving it to the student).

1.4.23. **FLOAT METAL ON WATER**

- What you need:**
1. A needle, razor blade, or thin wire gauze.
  2. A beaker/drinking glass, and a candle.



**How to do it:**

1. Fill the beaker/glass with water.
2. Take the needle or razor blade and show that the density of the metal is higher than that of water by dropping the object vertically in the water (see Sketch A).
3. Fish the needle out of the water and dry it off, or use another needle.
4. Now hold the needle horizontally as close as possible to the surface of the water (without touching the water) and drop it (Sketch B).
5. If this does not succeed, rub the needle against the candle before dropping it on the surface of the water.

**What questions to ask:**

1. Why is it not possible to float the needle on the water when it is dropped vertically?
2. Why does the needle have to be dry before floating it?
3. What purpose does the rubbing of the needle against the candle have?
4. What property of the water keeps the needle afloat?
5. How can we make a floating needle sink without touching it?

**How to explain it:**

When the needle is dropped vertically in the water, it pierces the water surface. The surface tension at that very small area of the needle point is not large enough to hold the needle afloat. But when the needle is dropped horizontally, parallel with the surface of the water, a much larger area of the water surface is involved, and the combined cohesion forces between the water molecules under and around the needle, which forms the **surface tension**, is large enough to hold the needle afloat. The rubbing against the candle makes the object more water repellent and increases the chance the needle will lie afloat on the film of water molecules.

1.4.24. **SINK THE PEPPER**

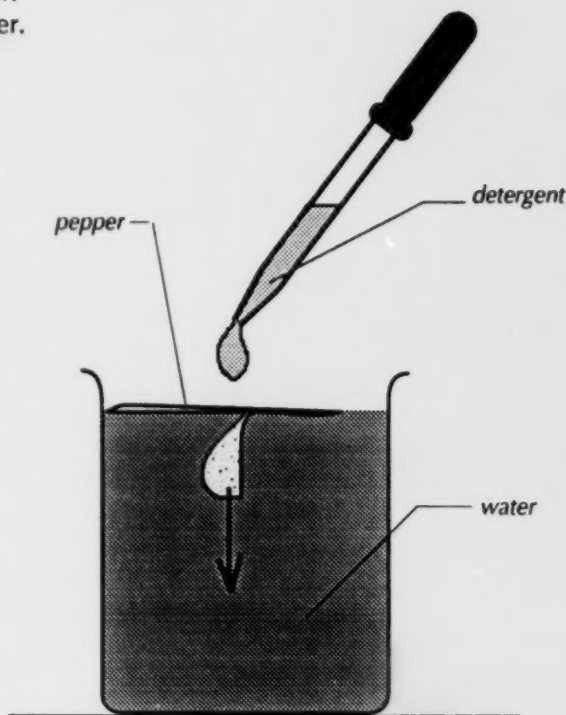
- What you need:**
1. A beaker/drinking glass or transparent container.
  2. Whole and ground pepper.
  3. Liquid detergent & dropper.

**How to do it:**

1. Fill the beaker/glass with water.
2. Show the students a whole pepper kernel and ask: "Will the pepper sink or float in the water?" Then drop it in the water: it sinks!
3. Now shake some ground pepper on the water surface. Ask: "Why is the same pepper now not sinking?"
4. Place a drop of detergent in the water and observe the fine pepper now sink to the bottom.

**What questions to ask:**

1. Why did the same pepper in fine state float on the water?
2. Do you think that pepper has a higher or lower density than water?
3. Did we change the density of the pepper by grinding it?
4. What did the detergent do to the water surface?
5. What forces were weakened between the water molecules when the detergent was added?



**How to explain it:**

By showing the sinking of the whole pepper kernel in the water, the students should be able to conclude that the **density** of pepper is higher than that of water. The grinding of the pepper is not changing the density of it, yet it floats on the water because the pepper particles are light enough to be held up by the **surface tension** of the water. The water molecules and their cohesive forces on the surface form a film, which can hold up relatively light objects like a needle, razor blade, gauze, etc.

Detergent has the property of breaking the **cohesive attraction forces** between the water molecules, and thus weakening the surface tension of water. The film on the surface is removed, and the pepper sinks.

1.4.25. THE DETERGENT PROPELLED BOAT

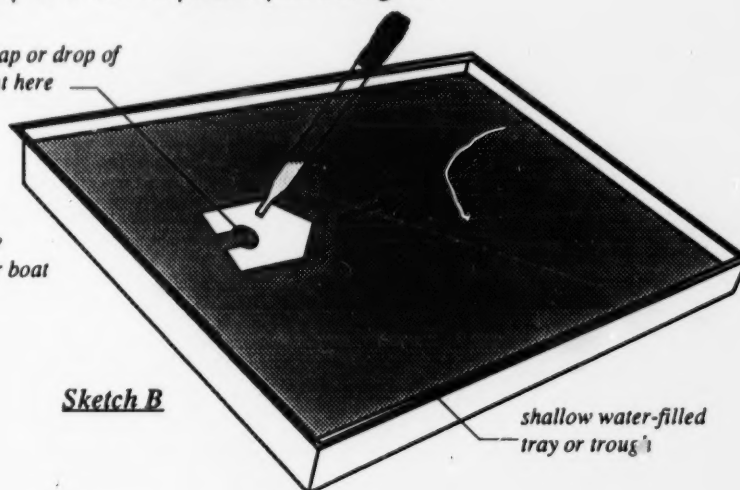
- What you need:**
1. A paper card (3x5"), a shallow tray or sink.
  2. A piece of soap or a few drops of liquid detergent.



**Sketch A**

touch soap or drop of  
detergent here

top view  
of paper boat



**Sketch B**

shallow water-filled  
tray or trough

**How to do it:**

1. Fill the shallow tray (or sink) with water.
2. Cut out a boat from the paper card in the form of Sketch A.
3. Let the paper boat float on the water and touch a corner of the soap block to the water in the center opening of the boat (or place a drop of liquid detergent here).
4. Observe the movement of the boat!

**What questions to ask:**

1. Why does the paper boat move forward only when the soap touches the water?
2. What made the paper boat be pulled forward?
3. What did the soap or detergent do to the cohesive forces between the water molecules?
4. What other shapes of boats would work the same way?
5. Would it work without a hole in the paper card?
6. What would happen if we touched the soap to the side of the boat?

**How to explain it:**

The soap touching the water or the drop of detergent in the water is breaking the **surface tension**. There are **cohesive forces** between the water molecules in front and in the back of the boat, as well as on both sides. By touching the soap towards the rear of the boat, these cohesive forces are broken in the rear but not in the front of the boat. This makes the boat to be pulled towards the front. Similarly, before the detergent was dropped, the water molecules on the surface of the water were pulling the boat on all sides with an equal force. After the detergent was dropped, the attracting force in the rear of the boat was eliminated, so that the resultant force is to the front. The shape of the boat is irrelevant. Any shape will do the same thing. When the surface tension on the left is broken, the paper shape will move to the right. The propelling can continue until the detergent has lowered the surface tension considerably, then the boat will sink!

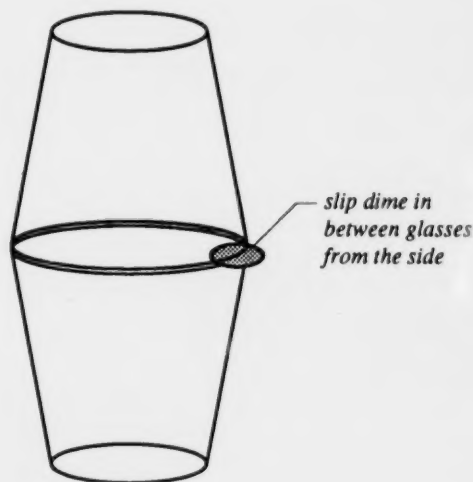


1.4.26. **THE WATER-FILLED CUPS**

- What you need:**
1. Two regular identical drinking glasses.
  2. A paper card and a dime (or razor blade).

**How to do it:**

1. Fill the two glasses with water up to the brim.
2. Place a paper card on one of them and turn the glass upside down while holding the card against the glass.
3. Let go of the card, place the inverted glass on the other water-filled glass, and slip out the card carefully (keeping the top glass exactly over the bottom glass).
4. Place a paper towel around the bottom glass to guard eventual spillage.
5. Ask students: "Can anything be added to the water inside the cups?" (Anticipated answer: 'No, not a thing').
6. Take the dime (or razor blade), push the dime in between the two glasses and slip it inside the glasses while holding the top glass.

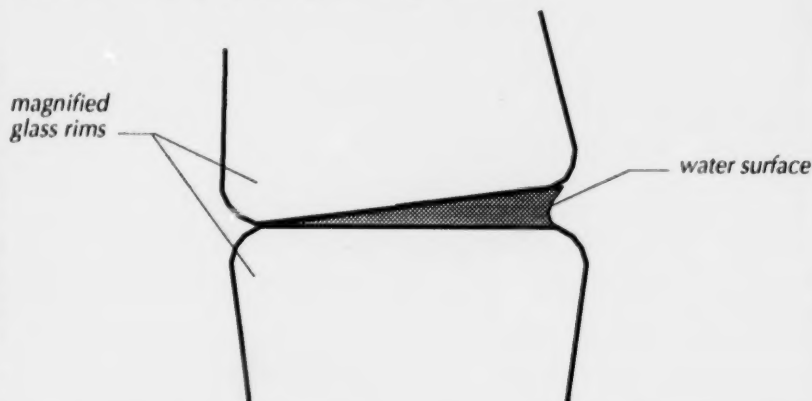


**What questions to ask:**

1. Why did the water not run out while the dime was slipped in?
2. Did any water spill while the coin was pushed in?
3. What indicated that some water must have run out?
4. What other objects could have been slipped inside the glasses?

**How to explain it:**

In placing the top glass upside down on the bottom water-filled glass, it was the air pressure that held up the card and the water. While the dime (or razor blade) is pushed between the two glasses, some water is running out, which can be detected from the

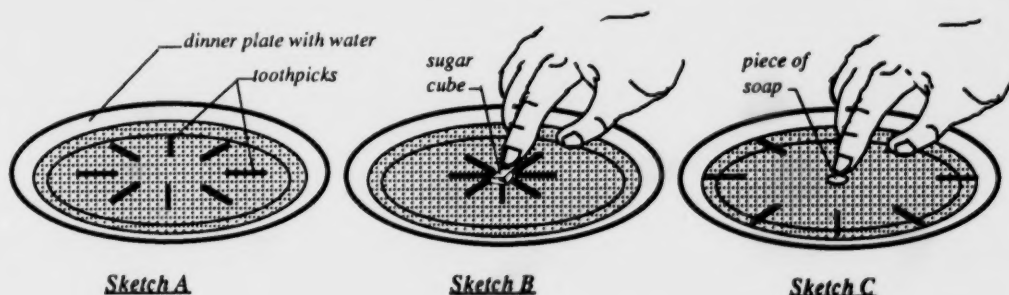


small air bubbles that float up in the top glass. The water in the top glass is held back mostly by air pressure pushing on the water surface between the two glasses. It is as if a film is covering the **surface of the water - surface tension**. Other objects that are as thin as a dime or even thinner could be slipped inside the glasses.



1.4.27. **THE FUNNY TOOTHPICKS**

- What you need:** 1. A dozen toothpicks (preferably the flat ones, but round is OK too)  
2. A dinner plate, or any other flat container for water.  
3. One or two sugar cubes. 4. A piece of soap or a drop of liquid detergent.



**How to do it:**

1. Fill the dinner plate almost full with water
2. Let 6-8 toothpicks radially float on top of the water - place them in the middle between the plate's center and the edge. (see Sketch A above).
3. Take a sugar cube and let the cube touch the water in the center of the plate and hold it there. Observe what the toothpicks are doing (see Sketch B above).
4. Now take the piece of soap (or the dropper with liquid detergent) and touch the water with the soap in the center of the plate. What are the toothpicks now doing? (Sketch C)

**What questions to ask:**

1. What made the toothpicks come together when we touched the water with the sugar cube?
2. What is the sugar actually doing with the water?
3. In what direction did the water actually flow when the sugar cube touched the center?
4. Why did the toothpicks fly apart when the soap touched the center of the plate?
5. What does soap do to the surface tension of water?
6. What other materials can be used to replace the sugar cube and get the same effect?
7. What substances can be used to replace the soap or detergent?
8. What other materials can be used instead of the toothpicks?

**How to explain it:**

The sugar cube is quite porous and has many capillary cavities in between the sugar crystals. Therefore when we touch the water surface in the center of the plate with the sugar cube, water is immediately **absorbed** into the cube, because of **capillary action**. Since the water at the surface flows towards the center, the toothpicks are coming with the flow, which is towards the center. Touching the water with soap in the center of the plate breaks the **surface tension** at this spot, eliminating the adhesive force at one end of the toothpick (the force between the water molecules and the toothpick). The resultant force between water molecules and toothpick is therefore from the center radially outward.

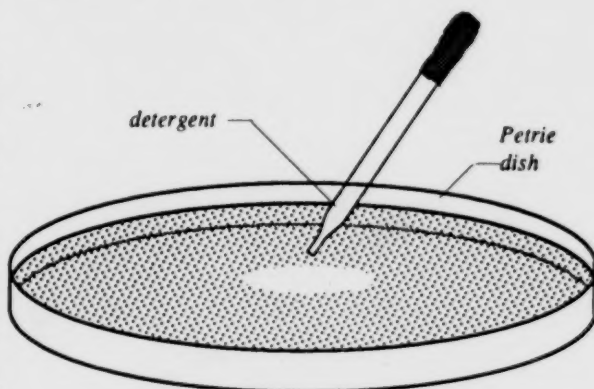
Other materials that may replace the sugar cube: a sponge, absorbent cotton, small capillary tubes, any water absorbent material. Replacing the soap or detergent: oil or alcohol, which will spread on the water surface and thus push the toothpicks radially out. This, however, is **not the same principle** as the breaking of the surface tension of water! Instead of the toothpick we may use any other material that floats on water: like, wooden matches, small corks, etc.

1.4.28. **THE DETERGENT-FEARING POWDER**

- What you need:**
1. A Petri dish (bottom or top)/shallow dish, a medicine dropper.
  2. Liquid detergent or soap (solid or powder).
  3. Lycopodium powder (or baking flour or fine pepper).

**How to do it:**

1. Fill a Petri dish/shallow dish about half full with water (place it on an overhead projector and project the dish on a screen - if using the Petri dish).
2. Sprinkle fine powder (face powder, baking flour, or fine pepper will do) on the water surface.
3. If you have liquid detergent: place a drop in the center of the Petri dish. Observe the spreading of the powder.
4. If you use solid soap: touch the water surface with a corner of the soap block. Observe!
5. If you have powder soap: drop one or two flakes on the water surface. Observe!



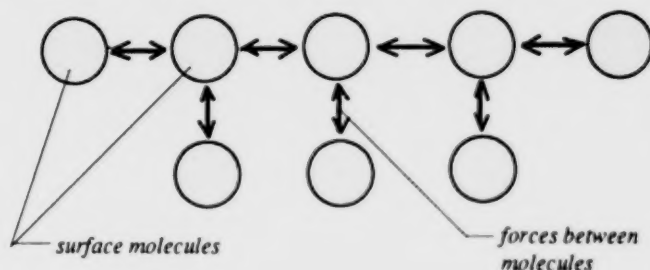
**What questions to ask:**

1. What made the powder move away from the detergent or soap?
2. What is the detergent doing to the surface tension of the water?
3. What forces are acting on the powder particles on the water surface?
4. What forces are acting between the water molecules on the water surface?

**How to explain it:**

At the surface of the water, the molecules form a film-like layer, where **cohesive forces** are most prominent. The surface molecules have only three sides, where cohesive forces act upon them, as no water molecules are above them. When these cohesive attraction forces are weakened by the detergent at a particular spot, the molecules that are farther away from this spot will pull these weaker held molecules toward them. As the water molecules move, they bring the powder particles with them.

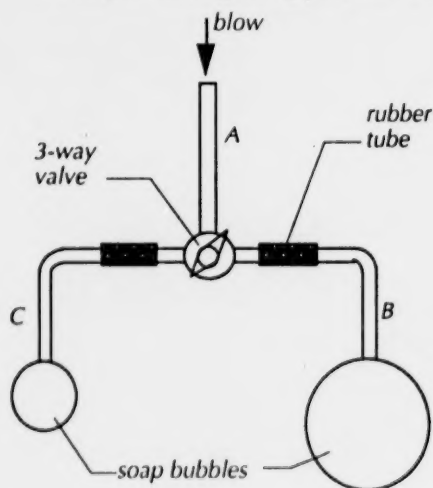
See Sketch A on right.



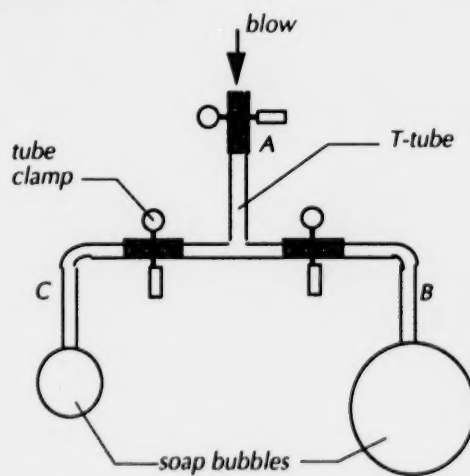
**Sketch A : Enlarged surface molecules**

1.4.29. **WHICH BUBBLE IS STRONGER ?**

- What you need:**
1. A three-way glass valve or a T-tube with 3 rubber tube clamps.
  2. Two (or three) short rubber/plastic tubes.
  3. Two L-shaped glass/plastic tubes.
  4. Liquid detergent, glycerine, a small beaker/cup.



Sketch 1



Sketch 2

**How to do it:**

1. Clamp the 3-way glass valve and connect the L-tubes to the short rubber tubes as in Sketch 1.
2. When no valve is available: use a T-tube with 3 rubber tubes and 3 tube clamps, and set the materials up as in Sketch 2.
3. Mix in a small beaker: 1 volume detergent, 2 volumes glycerine and 3 volumes of water.
4. Dip the end of the L-tubes in the detergent mixture by bringing the beaker with the mixture to the set-up.
5. Set the valve such that tubes A & B are connected (when using a valve), or press open clamp A & B. Blow a large bubble at the end of tube B. Now close clamp B, and blow a small bubble on C (by opening clamp A & C)..
6. Now freeze the air flow and ask: "Which one will blow which bubble up if they are connected to each other?"
7. Connect the two bubbles by turning the valve (when using a valve) or by pressing (opening) clamps B & C, (close clamp A) and observe.

**What questions to ask:**

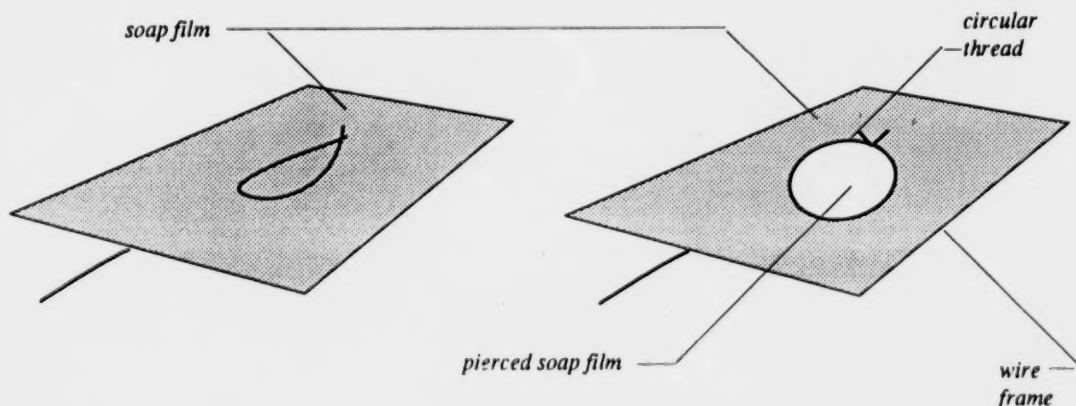
1. Which one is blowing which bubble up?
2. What can we conclude about the relationship between surface tension and radius of a soap bubble?

**How to explain it:**

The smaller bubble will blow up the larger one, once the two bubbles are connected. This is because the **surface tension** in a soap bubble is **inversely proportional to the radius** of the bubble: the larger the bubble, the smaller the surface tension, thus the lower the pressure inside it.

1.4.30. **THE THREAD CIRCLE IN THE SOAP FILM**

- What you need:**
1. A liquid detergent (preferably the one without additives), & glycerin.
  2. A square or rectangle wire frame and thread.
  3. A wide shallow container/tray (to fit the wire frame).



**How to do it:**

1. Make a soap solution by mixing the following liquids: 1 part detergent, 2 parts glycerin, and 3 parts of water (warm water if you make a fresh batch).
2. Place this soap solution in the shallow container, make a soap film by dipping the wire frame in the solution and taking it slowly out.
3. Make a small loop of thread (diam. 3-4 cm), wet it in the soap solution and lay it carefully in the soap film (see Sketch A).
4. Once the thread loop lies in the soap film, pierce the center of the loop with a dry object (pencil or dry finger).
5. Slant the wire frame, wiggle it, and observe the perfect thread circle move and travel throughout the whole frame!

**What questions to ask:**

1. What made the wrinkly thread turn into a perfect circle?
2. What does the circular loop indicate about the forces working on it.
3. The thread circle stays the same shape no matter where it is in the wire frame, what does this indicate about the forces working on it in the soap film?

**How to explain it:**

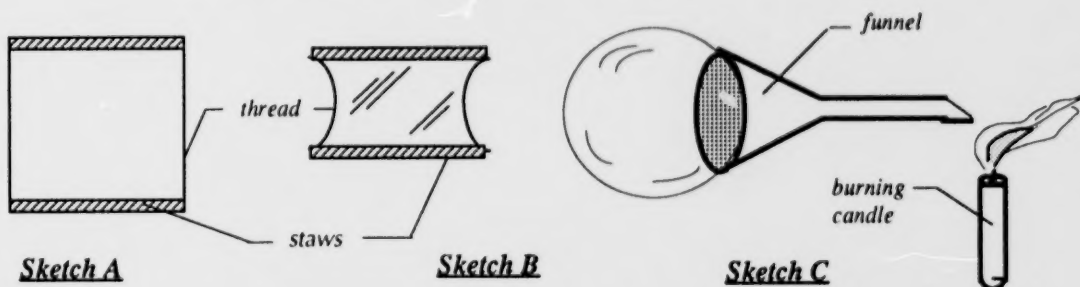
This demonstration shows that there is indeed a **tension** working in the soap film. The wrinkly thread loop lying in the soap film suddenly turns into a perfect circle, after the inside of the loop is pierced, because the forces inside the loop are eliminated, and **equal forces in all directions** at all points on the outside of the loop are working and pulling on it.

By tilting and wiggling the wire frame, the thread loop can move throughout the frame without changing shape, as a result of the **cohesive forces** of the soap film that are of equal magnitude throughout the whole film.



1.4.31. **THE STRONG SOAP FILM**

- What you need:**
1. Two soda straws & thin cotton thread.
  2. A medium size glass or plastic funnel, a candle.
  3. Liquid detergent (no additives e.g. JOY), glycerin.



**How to do it:**

1. Make a soap solution by mixing 1 part of detergent, 2 parts of glycerin, and 3 parts of water.
2. Push the thread through the two straws (put the thread in one end and suck from the other end of the straw) and tie the ends of the thread together to make a square frame - see Sketch A).
3. Dip the frame into the soap solution and pull them slowly out, holding the straws close together and then spreading them apart and observe what the thread is doing (see Sketch B).
4. Light the candle and secure it to the table top.
5. Hold the funnel by its long end and dip it into the soap solution. Blow through the funnel and form a medium sized bubble, but make sure that you let the bubble stick to the funnel!
6. Point the funnel opening (long end) to the candle flame and observe the candle flame (see Sketch C).

**What to ask:**

1. What made the threads between the straws curve?
2. What would happen if the soap film between the straws is punctured?
3. What happened to the candle flame?
4. What happened to the soap bubble in the funnel?
5. What do both events indicate about the forces in a soap film?

**How to explain it:**

In the soap film between the wires and thread there exists a force called: **surface tension**. It consists of adhesive forces between the liquid molecules and the solids (called **adhesion**), and cohesive forces between the molecules of the soap solution (called **cohesion**).

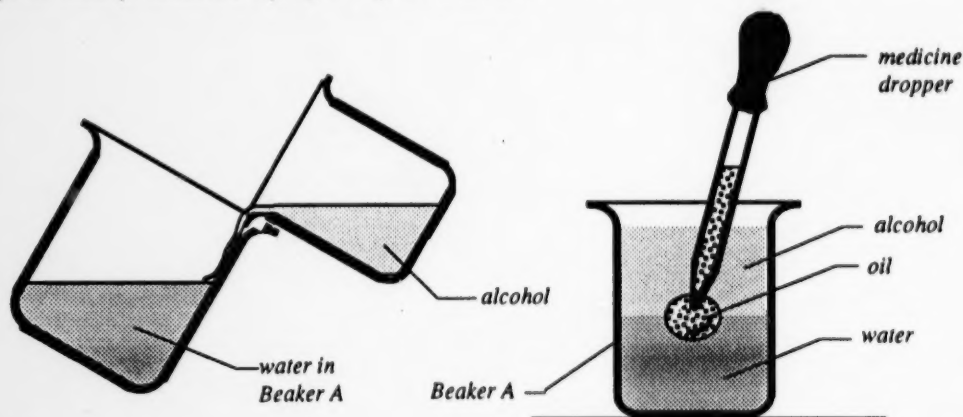
This same adhesive/cohesive force or sometimes also called **capillary force** exists in the bubble which is attached to the funnel. This force is pushing the air in the funnel out of the opening and is almost strong enough to blow the candle out.

Examples of capillary forces in action are: the sucking of water from the roots of plants travelling into the top leaves (also called **osmotic pressure**); the gluing of two pieces of plexiglass with a thin organic liquid (by placing a few drops of the liquid between the two solid surfaces).



1.4.32. **THE FLOATING OIL SPHERE**

**What you need:** 1. A large, wide test tube or small beaker (100 ml). 2. A medicine dropper.  
3. Ethyl or methyl alcohol, frying or light motor oil.



**How to do it:**

1. Pour about 50 ml of water in the beaker (or test tube).
2. Hold this beaker in a slant and slowly pour the alcohol on top of the water (about 50 ml - an equal amount as the water).
3. Let the beaker stand on the table.
4. Fill the medicine dropper with oil, bring the opening of the dropper in the beaker where the two liquids meet, and squeeze the oil out. Then withdraw the dropper carefully out of the liquid.

**What to ask:**

1. Why does the alcohol float on top of the water?
2. What would happen if we poured the alcohol carelessly on top of the water?
3. Is alcohol completely immiscible with water?
4. Why does the oil take the shape of a sphere?
5. Why does the oil sphere stay between the two layers of liquid?
6. What would happen if the oil was squirted out of the dropper in the alcohol layer and not where the two liquids meet?
7. What would happen if the oil was squirted out in the water layer?
8. What would happen if the oil was squirted out in water only?

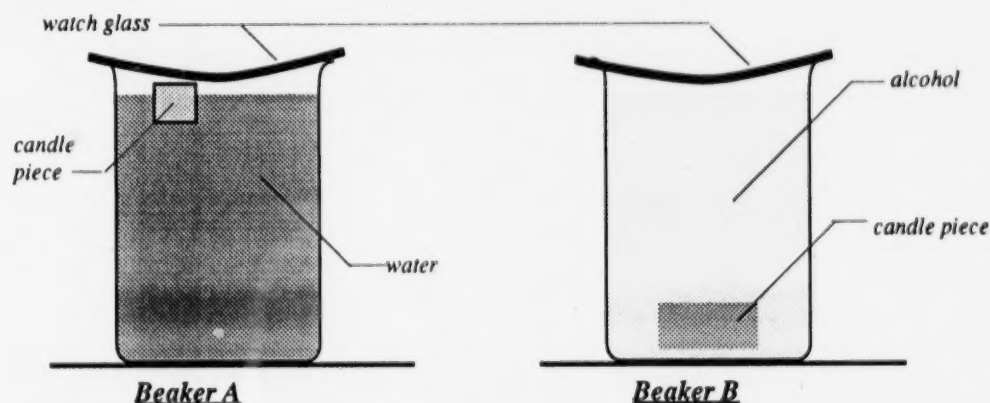
**How to explain it:**

As ethyl alcohol has a **density** of 0.794 and methyl alcohol even less than that, it can float on water and form a layer. It is not totally **immiscible** with water, but when poured slowly and carefully on the water it can form a layer and stay above it. Where the two liquids meet, however, the water and alcohol mix and form a liquid with a density very close to that of oil. This is why the oil forms a perfect sphere between the two liquid layers.

A sphere is formed because it has the smallest surface area as compared to other three dimensional shapes. When the beaker is left standing, the alcohol evaporates slowly, and the oil sphere moves up slowly until it reaches the surface and then the sphere is knotted off at the top and slowly becomes a flat circle when all the alcohol has evaporated.

1.4.33. **THE FUNNY WATER**

**What you need:** 1. Two identical beakers/drinking glasses, two identical watch glasses or covers.  
2. One small and one larger piece of candle.  
3. Alcohol (methyl, ethyl, or isopropyl, or duplicating fluid, or rubbing).



**How to do it:**

1. Fill beaker A about 3/4 full with water and beaker B with the same amount of alcohol and cover them with the watch glasses/covers (do not reveal to students that the liquids are different).
2. Show the students the two pieces of candle: drop the short piece in beaker A and the longer candle in beaker B.
3. Ask: 'Why is one candle floating and the other sinking?' 'What will the candles do if I switch them around?'
4. Drop the long candle in beaker A (it still floats) and the short one in beaker B (it sinks).

**What to ask:**

1. Why does the candle float in beaker A?
2. Why does the candle sink in beaker B?
3. What does it depend on whether something floats or sinks in water?

**How to explain it:**

The alcohol has a lower **density** than water. This is why the candle sank in the alcohol and stayed afloat in water. Some students may suggest that it sank in beaker B because it is longer than the other piece that stayed afloat. But then, after switching the pieces of candle around, the longer candle stayed afloat in the water and the shorter one sank in beaker B. This most likely will give students a clue, that the liquid in beaker B is some kind of "funny water." This liquid may be methyl, ethyl or isopropyl alcohol, which all have a density of around .76. The density of water is 1, and that of wax in the vicinity of .85.

Density is defined as the ratio of mass and volume of a substance.  $D = \frac{M}{V}$  in which D = Density, M = Mass, and V = Volume.

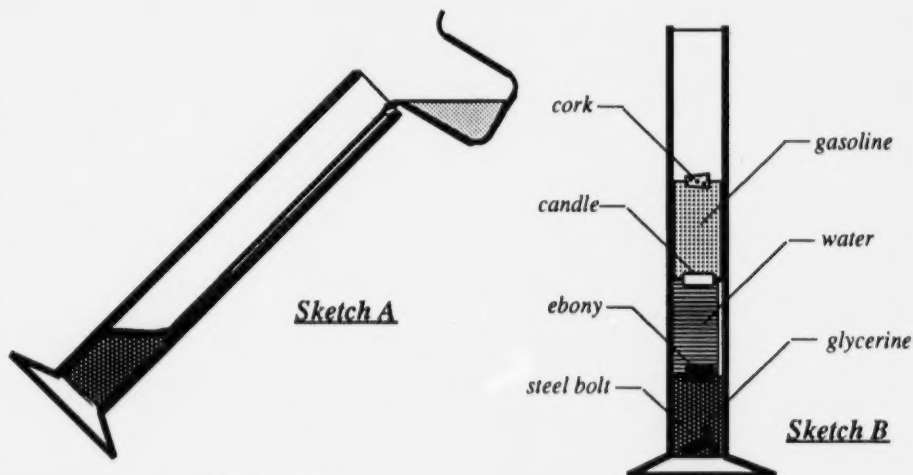
Whether something sinks or floats depends on the relative density of the object compared to that of the liquid it is immersed in. Any object that has a density between that of water (1) and that of alcohol (.76) may be used for this demonstration.

1.4.34. WHICH WILL FLOAT WHERE ?

- What you need:** 1. Glycerin/clear syrup & Kerosene (or gasoline).  
2. A piece of steel (bolt or nut), a piece of ebony wood, paraffin or candle), and a cork.  
3. A long thin measuring cylinder (100 ml), three small beakers.

**How to do it:**

1. Pour about 20 ml of glycerin/syrup in the cylinder, followed by 20 ml each of water and gasoline. Do this pouring by holding the cylinder slanted so the liquids will slide on top of each other (Sketch A).



2. Now pick up the piece of ebony, and ask the students: "Where will this object end up, between which layers, or maybe on the bottom?"
3. Pick up the steel bolt and ask the same question (record students answers) then drop it in the cylinder and observe.
4. Do the same with the piece of candle and the cork.

**What to ask:**

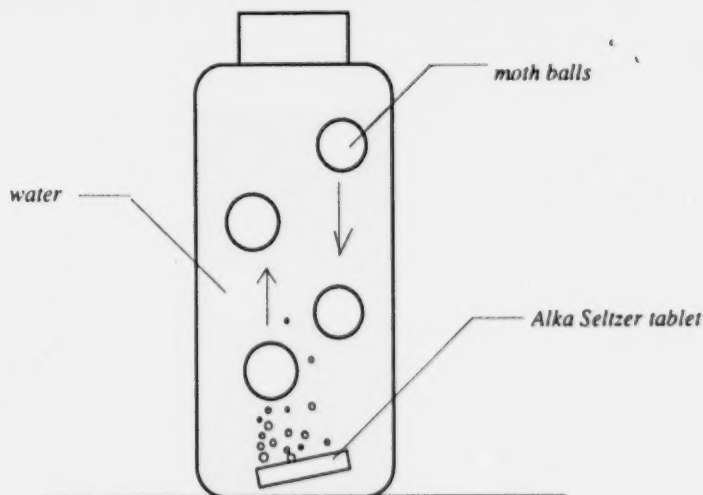
1. Where did the piece of steel end up, was it on the bottom?
2. Where did the other objects end up floating?
3. How do the densities of steel and mercury compare?
4. How do the densities of the four liquids compare?
5. If we know that the density of water equals 1, what can we say about the densities of ebony, steel, and glycerin/syrup?
6. What can we say about the densities of paraffin, cork, and gasoline?
7. On what property of the material does it depend, whether an object will float on a liquid or sink in it?

**How to explain it:**

In ascending order the **densities** of the solids and liquids are as follows: cork, kerosene/gasoline, paraffin/candle, water (1), ebony, glycerin/syrup, steel. This demonstration shows that even ebony can float on a liquid, as long as the liquid has a higher density than ebony (see the Table of Densities in the Appendix). The three layers of liquid can be used to roughly determine the density of an object. This can be done by just dropping the object in the cylinder and observing where the object ends up floating. In the order above, all those preceding water have a density of less than 1. Those that come after water have a density of greater than 1.

1.4.35. **THE BOBBING MOTH BALLS**

**What you need:** 1. A graduated cylinder or narrow tall jar.  
2. Four or five moth balls. 3. One or two Alka Seltzer tablets.



**How to do it:**

1. Fill the cylinder or jar with water.
2. Drop an Alka Seltzer tablet (or any tablet that produces carbon dioxide gas) in the water, and immediately afterwards the moth balls.
3. Let the students observe the moth balls (bobbing up and down).

**What to ask:**

1. Why do the moth balls sink in the beginning (when they were dropped)?
2. What makes some moth balls bob up?
3. Why do the moth balls float only for a short while at the surface of the water?
4. What is the purpose of the Alka Seltzer tablet?
5. Would the moth balls bob up and down without the Alka Seltzer?
6. What do you observe the difference is between the rising and sinking moth balls? (Observe closely!)
7. What other liquid would give off carbon dioxide bubbles by itself?

**How to explain it:**

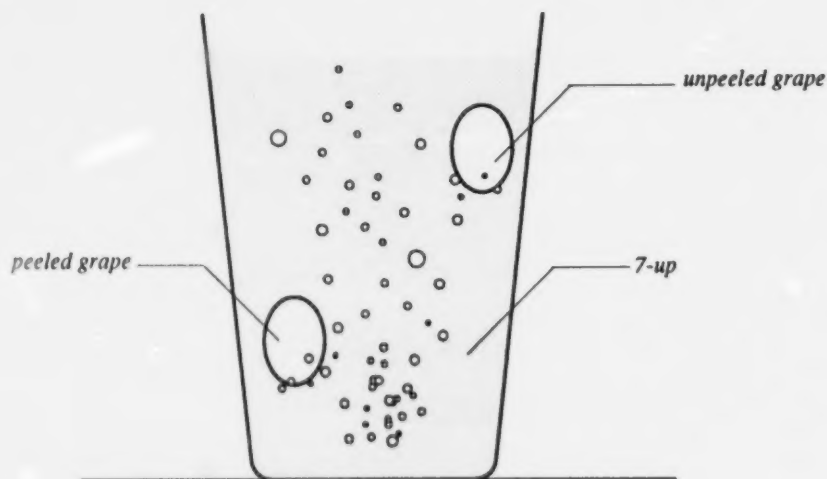
The moth balls have a **density** of a little over 1, so that they just sink in water. When the gas bubbles from the Alka Seltzer tablet adhere to their surfaces, they get lighter and rise up. As soon as they reach the surface of the water, the bubbles burst. This makes the moth ball become heavier again—causing it to sink.

If Alka Seltzer tablets are not available, other tablets that fizz in water may be used. Soda pop drinks, like 7-Up could be used as a replacement. These have the gas already dissolved in them and when they are poured into the jar, the bubbles escape, giving the same effect as the Alka Seltzer tablet's bubbles.



1.4.36. WHICH GRAPE IS HEAVIER ?

**What you need:** 1. Fresh grapes & 7-Up soda pop. 2. A clear drinking glass.



**How to do it:**

1. Pour and fill the glass with 7-Up soda pop.
2. Peel one grape (take the skin off and leave the grape whole).
3. Take another unpeeled grape in the other hand and pose the students the question: 'Which of the two grapes is heavier?' (Anticipated answer: 'the unpeeled one'—which is true!).
4. Drop both grapes (the peeled and unpeeled one) in the 7-Up and observe what they do.

**What to ask:**

1. Why does the peeled grape sink to the bottom?
2. Which of the two grapes is lighter in weight?
3. What makes the unpeeled grape float?
4. Would an unpeeled grape also float in water?
5. Could we do this same demonstration with water and Alka Seltzer?
6. What property does the grape peel have?

**How to explain it:**

This demonstration is also very suitable in the teaching of adhesive and cohesive forces (bubbles adhering to the grape skin). The unpeeled grape has water repelling—**hydrophobe**—properties and thus the  $\text{CO}_2$  bubbles from the 7-Up can adhere to this surface.

The peeled grape lacks this **hydrophobe** skin (it is **hydrophyl**: water-attracting) and the bubbles of the 7-Up have no way of adhering to the grape. This causes the grape to stay at the bottom of the glass. The unpeeled grape becomes lighter in weight, because of the adhering bubbles, and rises to the surface of the liquid. There it loses some of the bubbles to become heavier again. It may sink a while, picking up more bubbles, to bob up to the surface again.

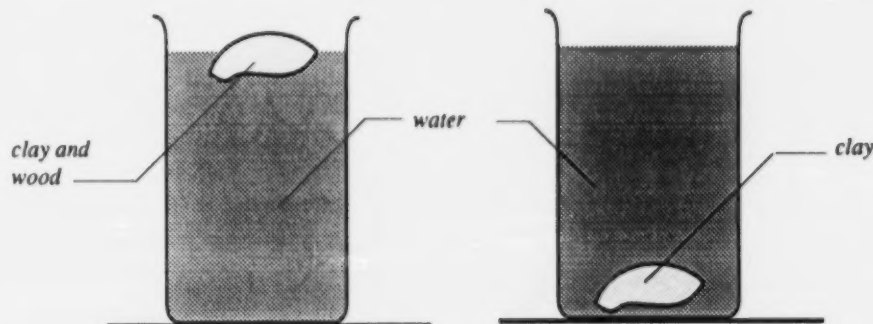


1.4.37. THE DIFFERENT CLAY STICKS

**What you need:** 1. Molding clay and a short wooden stick.

2. A technical balance or equal arm balance.

3. Two beakers (glass or clear plastic).



**How to do it:**

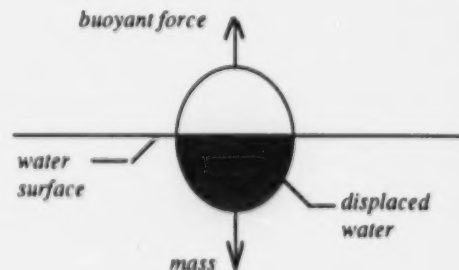
1. Wrap just enough clay around a short wooden stick, so that it would just barely float in water.
2. Place this on one pan of the equal arm balance and weigh off the same mass of clay on the other pan.
3. Roll a cylinder out of this mass of clay. You are now ready for the inquiry demonstration.
4. Show the students the two beakers filled with water and the two clay cylinders (to be placed in the water).
5. Show them that they weigh exactly the same, by placing them on each pan of the equal arm balance.
6. Now drop them in the two beakers with water (one sinks and one floats!).

**What to ask:**

1. Why does one clay cylinder sink and why does the other float?
2. What property is the same for both sticks?
3. What property does it depend on whether an object sinks or floats in a certain liquid?
4. What force is holding the floating object afloat?

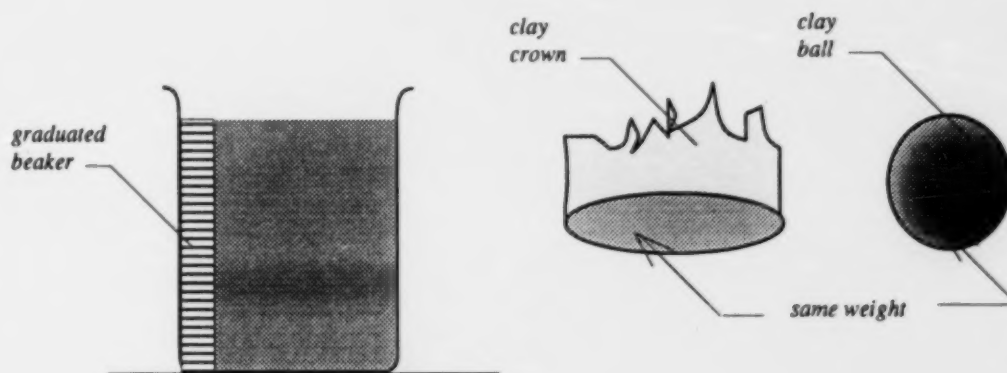
**How to explain it:**

Although the mass of the two clay sticks are equal, the volume is definitely not the same, because the much lighter wooden stick is inside the one that floats. Since the density may be calculated from  $D = M/V$ , it can be seen that the density of the floating cylinder is smaller than the one that sinks. The force that holds up the floating cylinder is the **buoyant force**, which is the mass of the displaced liquid (water in this case). If the mass of the displaced water is the same as the mass of the object, it will float. If the former is less than the mass, the object sinks.



1.4.38. **IS THE CROWN MADE OF PURE CLAY ?**

- What you need:**
1. Molding clay (insoluble in water), some saw dust or wood chips.
  2. A graduated cylinder or measuring cup.
  3. An equal arm balance or technical balance.



**How to do it:**

1. Make "impure" clay by mixing some sawdust or wood chips in the clay.
2. Now make an intricate shape (like a crown) out of the "impure" clay, and ask: "How can I find out whether the crown is made of pure clay or not?" (or tell the story of the King and Archimedes).
3. Weigh pure clay on the balance of the same mass as that of the crown.
4. Determine the volume of the crown and the pure clay by immersing them one by one in the graduated beaker. (Read off the water level before and after immersion and calculate the difference).

**What to ask:**

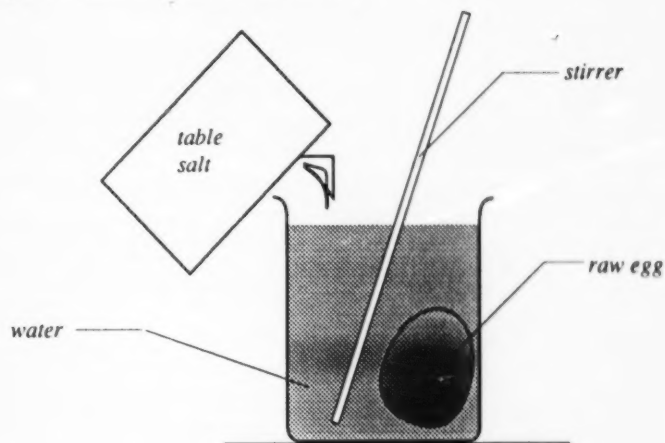
1. If the crown and the clay ball were to displace the same amount of water, what may we conclude about the crown?
2. If the crown is made of impure clay, how would the two volumes differ?
3. Why does the ball need to be of the same mass as the crown?
4. What property are we actually determining of the crown?
5. What property is determined by immersing the object in water?
6. How did Archimedes determine the density of the King's crown?
7. Is density a specific characteristic of a substance?

**How to explain it:**

The King suspected that his crown maker had cheated on him (by mixing in copper with the gold), so he summoned Archimedes to check whether his crown was made of pure gold or not. Archimedes made use of the **definition of density** ( $D = M/V$ ); so he weighed in pure gold, the same mass as that of the crown, and then determined the volume of the crown and the chunk of pure gold by immersing it in water. If the crown were made of pure gold, the density of both objects should be the same, thus also the volume of the **displaced water** should be the same. If the volume of the crown came to be larger than that of the gold chunk, it would have been made of impure gold - and its maker would have cheated the king.

1.4.39. **FLOAT THE EGG WITH SALT**

- What you need:**
1. A raw chicken egg & table salt.
  2. A large beaker or plastic container.



**How to do it:**

1. Fill the beaker/container about 2/3rd full with water.
2. Ask students: 'What will the egg do in the water, sink or float?' Immerse the egg now very carefully in the water.
3. Add salt to the water while stirring carefully (remember, it is a raw egg), until the egg starts to float.
4. Try to dissolve other chemicals (instead of salt) in the water, like: sugar, baking soda, corn syrup.

**What to ask:**

1. What would the density of the raw egg be compared to pure water?
2. By adding the salt to the water, what property was increased?
3. What two entities are we comparing, when we want to know whether an object will float in a particular liquid or not?
4. Would the egg float in alcohol?
5. How can we determine the volume of an egg?
6. How can we calculate the density of an egg?

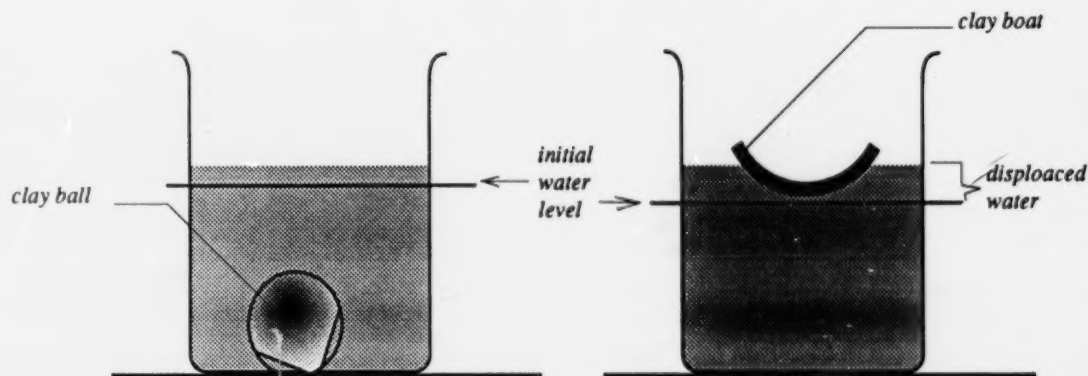
**How to explain it:**

From the behavior of the egg in water, it can be seen that the **density** of the raw egg is a little larger than that of pure water, since it actually sank in the water. It can actually be determined by weighing the egg and finding the volume of it by measuring the **displaced water** (the difference between the water levels before and after immersion), and by dividing this volume into the mass (weight) of the egg.

By adding the salt to the water, the density of the water is increased. The mass of the displaced water is therefore also increased, and as this mass equals the **buoyant force**, which is the force upward, the egg gets pushed upward with a greater force, and thus at a certain point it floats up. At this moment, the buoyant force is equal to the egg's mass. For this same reason it is much easier to swim in sea water as compared to fresh water.

1.4.40. CAN YOU MAKE CLAY FLOAT ?

What you need: 1. A lump of molding clay. 2. A large beaker or transparent container.



How to do it:

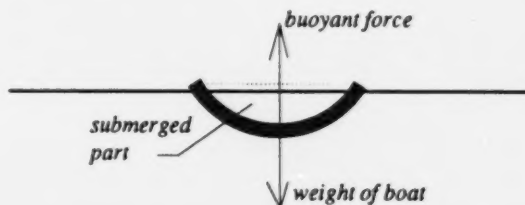
1. Make a ball of clay with a diameter of about 5 cm.
2. Fill the beaker half way with water and mark off the water level.
3. Ask students: "Will clay float or sink in water?" Plunge the clay ball in the water, mark off the water level, and take it back out.
4. Transform the same ball of clay into a small boat (make sure it is watertight), and let it float on the water.
5. Draw students' attention to the water level with the floating clay boat on the water.

What to ask:

1. Was the clay ball heavier than the clay boat?
2. Which of the two displaced more water?
3. What is the volume of the displaced water equal to?
4. What is the weight of the displaced water equal to?
5. Would we be able to float iron or lead this same way?

How to explain it:

The clay ball and clay boat were of the same weight, because the boat was made of the one and the same clay ball, and as **mass is conserved** and no clay has been taken away or added, the mass and thus the weight is the same. The boat, however, **displaced** more water because of its shape. The volume of this displaced water is equal to the volume of the submerged part of the boat or ball, whereas the **weight of the displaced water** is equal to the **buoyant force**, which is the force upward. This is equal to the mass of the clay boat when floating, but less than the mass of the clay ball (this is why the ball sinks).





1.4.41. **MAKE YOUR OWN LETTER SCALE !**

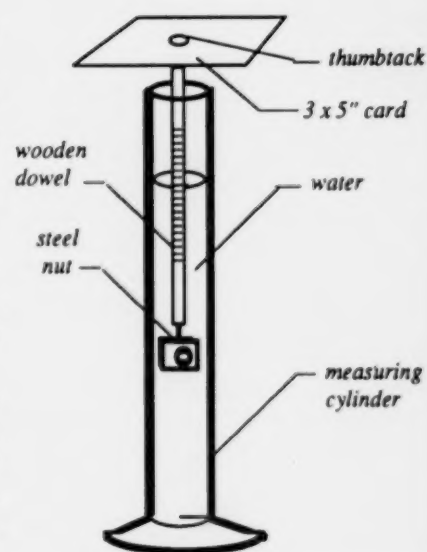
**What you need:** 1. A measuring cylinder or tall slim jar.

2. A 20-30 cm piece of broom handle, or wooden dowel or pencil with an eraser end, and 10-20 pennies.

3. A 3x5 card, thumbtack, a small metal weight (steel nut).

**How to do it:**

1. Tie a short thread to the weight and hook it to one end of the wooden dowel with a small nail or thumbtack.
2. Place it vertically in the water-filled cylinder to test whether it will float about half way in the water (if it floats too deeply, the weight is too big).
3. Attach the 3x5 card to the other end of the dowel with the thumbtack.
4. You are now ready to calibrate your home-made scale:
  - a) Place a pencil mark at the water surface on the dowel.
  - b) Put ten pennies on the card, and mark the dowel at the water surface (meniscus).
  - c) Take the whole scale out of the water and divide the distance between the two marks in ten equal parts.
5. You are now ready to use the scale to weigh letters or small objects weighing less than 1 ounce or 30 grams (each line of the scale indicates .1 ounce or 3 grams; this depends on the weight of the coins used).



**What to ask:**

1. What is the function of the small weight at the lower end of the dowel?
2. What would you say the density of wood is compared to water?
3. What other material could be used instead of a wooden dowel?
4. What variables influence the sinking distance of the dowel?
5. The capacity of the scale might be only 2 ounces or 60 grams; how can we increase its capacity?
6. How would using 2 or 3 dowels (bundled) influence the sinking distance?

**How to explain it:**

The function of the small weight at the bottom end of the dowel is to make the dowel sink half way in the water and also to keep it floating vertically. The more dowels are used or the larger the diameter of the dowel, the greater the capacity of the scale, as the **displaced water** is increased and thus also the **buoyancy force**.

The placing of already known weights on the scale makes it possible to calibrate the wooden dowel against the sinking distance. In a less dense liquid the scale would float much lower, and in a denser liquid it would float much higher.

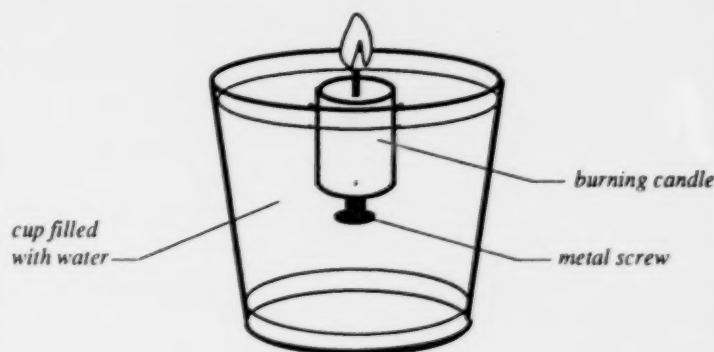


1.4.42. THE WATER CANDLE

**What you need:** 1. A drink glass or glass beaker.  
2. A thick short candle, a small metal screw (or thumbtacks). Procedure:

**How to do it:**

1. Attach the screw or thumbtacks to the bottom of the candle.
2. Fill the drink glass with water and let the candle float in it (if it sinks the screw size is too large or you used too many thumbtacks; use a smaller one or use less thumbtacks).
3. Light the candle and start asking questions.



**What to ask:**

1. What is the function of the screw/thumbtacks in the bottom of the candle?
2. When the candle burns shorter, will the water extinguish the flame?
3. Will the candle float higher or lower in the water over time?
4. With time, will the density of the floating system change?
5. With time, will the buoyancy of the system change?
6. Will the candle actually become shorter over time?
7. When will the candle flame be extinguished?
8. What shape will the top of the candle be forming?
9. Will the candle tip over if the flame burns unevenly?
10. What would a long narrow candle do when floated in water and then lit?

**How to explain it:**

The purpose of the metal screw or thumbtacks in the bottom of the candle is to make the candle heavier at the bottom, thus making it float in a vertical position. The top of the candle will burn leaving a concave cavity containing the molten wax. The outside of the candle which is in touch with the water stays cool and is therefore not melting. Slowly, however, the wax is burning off and the total weight/mass of the candle gets smaller.

As the mass as well as the volume of the candle became smaller, the **density** (mass over volume) stays the same - at least in the beginning of the burning process -, thus the part that is above water stays above water (just like 1/10th of an ice cube stays above water no matter what size of cube). But towards the end of the candle, the density becomes greater (because of the screw) and it will reach a point where the buoyancy force is not great enough to keep the candle floating.

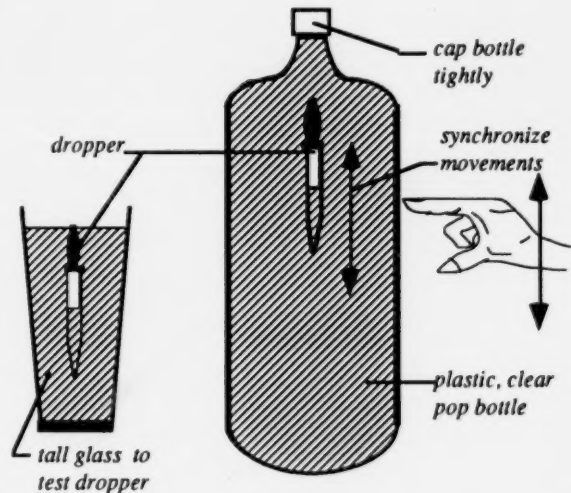
By burning a candle this way, molten wax drippings on the outside of the candle are avoided. Almost all the wax will be burned off - a most efficient way of burning a candle!

1.4.43. **THE MAGNETIC FINGER**

**What you need:** 1. An empty 2-liter soda pop plastic clear bottle.  
2. A small medicine dropper  
3. A tall drinking glass.

**How to do it: PREPARATION**

1. Take the stiff bottom of the clear, plastic bottle off by forcing it down from the transparent part and then completely fill the bottle with water. (Use the stiff part as a stand on the table)
2. Fill the tall drinking glass full with water.
3. Test the dropper for buoyancy: fill it half full with water by pushing the rubber bulb and sucking water into it; place it in the drinking glass - the dropper should **just** float. (If it sinks, push a few drops out of the dropper and test again).
4. Now place the dropper in the water-filled bottle and cap the bottle quite tightly. Now you are ready for the demonstration.



**DEMONSTRATION**

5. Hold the bottle by the bottom in your left palm and point with your right index finger to the dropper, saying: "As soon as I touch the bottle, my finger will become a magnet and the dropper comes with it". - Move your right finger down along side the bottle and simultaneously press the bottle with your left hand.
6. Practice the synchronization of finger movement and pressing!

**What to ask:**

1. Does your finger really become magnetic?
2. What makes the dropper sink?
3. What did the water level inside the dropper do when the left hand pressed the bottom of the bottle?
4. What did we have to do to make the dropper move up?
5. What is more compressible? Water or air?
6. Where do we find this principle applied in daily life?

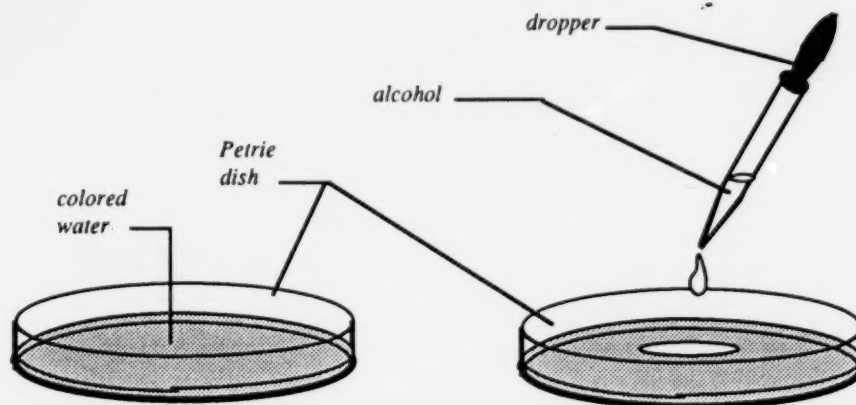
**How to explain it:**

By pressing the bottom of the bottle with our left hand (if we are right-handed) and moving our right index-finger down along side the bottle, then easing the pressure and moving the finger up, it seems like the dropper is being pulled down and up by the finger (as a magnet). It is just that the pressing of the bottle and the movement of the finger has to be as synchronized as possible. The pressing of the bottle compresses the air in the dropper (**air is more compressible than water**) and more water gets in the dropper making it heavier, and thus the dropper sinks. When releasing the pressure, the relatively compressed air expands and the water is pushed out of the dropper, making it lighter and thus making it float.

This same principle is used in submarines: in order to submerge, they just need to get heavier. They can do that by pumping in water. To surface, they need to get lighter and this they can do by pumping the water out.

1.4.44. THE CLEARING SPOT

**What you need:** 1. A glass Petri dish or any other shallow dish and a medicine dropper.  
2. Alcohol (methyl-, ethyl-, or isopropyl-) (rubbing alcohol or duplicating fluid).  
3. Food coloring.



**How to do it:**

1. Cover the bottom of the Petri dish with a thin layer (1 mm) of water and color with a few drops of food coloring.
2. Mix thoroughly and place the dish on the overhead.
3. Put a few drops of alcohol in the center of the Petri dish with the medicine dropper.  
What do you observe?

**What to ask:**

1. What did you observe after the alcohol was added?
2. What would happen if the water layer was much thicker?
3. What other liquids can be used to replace the alcohol and still obtain the same effect?
4. What would happen if we exchanged the liquids? (A few drops of water on colored alcohol?)
5. What would happen if the alcohol was dropped on the side of the dish? (Not exactly in the center?)
6. What do you observe if you drop the alcohol close to the water edge in the clearing hole?

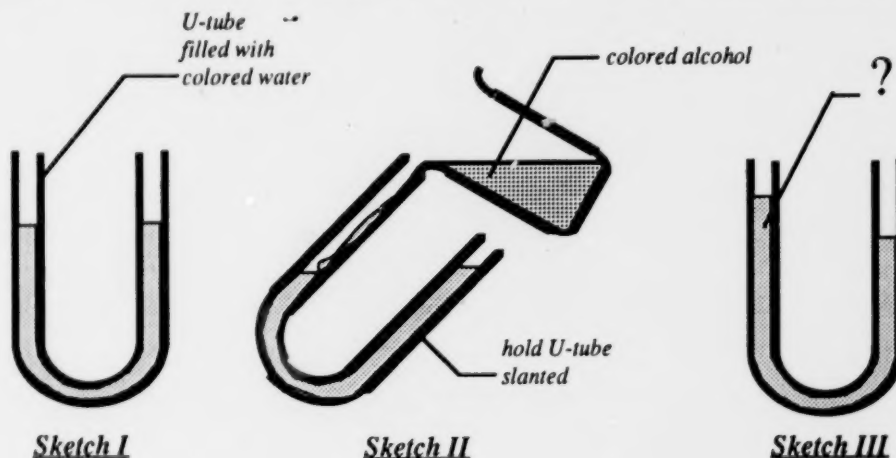
**How to explain it:** The alcohol drops will push the thin water layer away and form a small colorless circle in the center of the Petri dish. This happens because alcohol is rather **immiscible** with water, meaning that the two liquids do not mix when they are not stirred. If the two liquids were **miscible**, no clearing spot would be formed, this is also the case when the water layer is too thick.

After the clearing spot is formed, let a few alcohol drops fall close to the water edge inside the clear spot: the water edge forms a protrusion and wrinkles are formed; the colored edge moves as if it were "swallowing" the alcohol and moves back. This occurs because the alcohol slowly **mixes** with the water. Over time the clearing spot becomes smaller and smaller until the bottom of the dish is completely covered again. This happens because the alcohol **evaporates** and thus there is nothing to repel the water.

Try to do this demo with a plastic Petri dish!

1.4.45. **THE UNLEVEL COMMUNICATING TUBE**

**What you need:** 1. A communicating tube (U-tube or tubular vase) 2. Water and alcohol (methyl or ethyl). 3. Food coloring (green, red or blue) 4. Two small beakers or plastic cups.



**How to do it:**

1. Fill one beaker with water and the other with alcohol; and color both with the same coloring - make sure that the color intensity is exactly the same.
2. Fill the communicating tube with the colored water, so that no bubbles are found in the whole tube. (the meniscus in both legs of the tube should be level now)- see *Sketch I*
3. Put the beaker with the water away, show only the water filled communicating tube and the beaker with the colored alcohol to the audience (do not mention what the liquids are!).
4. Now pour the alcohol very carefully in one of the legs of the communicating tubes by slanting the tube and pouring the alcohol slowly - see *Sketch II*.  
What do you observe?- see *Sketch III*.

**What to ask:**

1. Why is the meniscus in both legs of the communicating tube not level (equal in height)?
2. Why does the pouring of the liquid have to be slow?
3. What other liquids could be used instead of the water?  
Instead of the alcohol?
4. What would happen if we interchanged the alcohol and the water? How would the meniscus in both legs compare now?
5. How could we get the water levels to be even/level?
6. Will the water levels be even/level when we slant the whole apparatus?

**How to explain it:**

This illustrates the basic principle of communicating tubes or vessels: **whenever two or more tubes, whether vertical or slanted, are connected with each other (communicating), the liquid level in all the legs will be level (same height), provided that the same liquid is being used.** This very same principle is being used to find two points that are level at the opposite corners of a house foundation. A long, clear plastic hose is almost completely filled with water, and the two ends of the hose will act as the two legs of the **communicating tubes**. In the above case, alcohol, a less dense liquid, is poured in one leg and thus the meniscus is higher in this leg, to compensate the pressure from the other leg. A denser liquid (like glycerine) would bring the meniscus in this leg lower than that in the other leg. (Compare with: **COMMUNICATING CYLINDERS**)

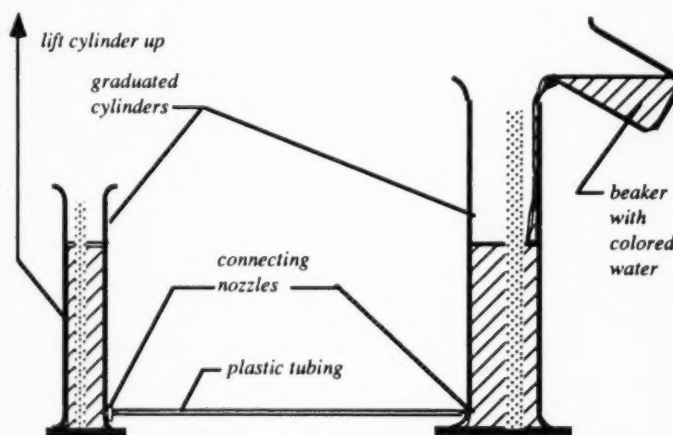


1.4.46. THE COMMUNICATING CYLINDERS

- What you need:**
1. One 400 or 500 ml plastic, clear graduated cylinder.
  2. One 100 or 250 ml plastic, clear graduated cylinder.
  3. Plastic tubing - about 30 cm / 1 ft long (smallest diameter; tubing for a drip system for watering plants may be used)
  4. Connecting nozzles, and a tool to puncture small holes in the cylinders.

**How to do it:**

1. Puncture a small hole close to the bottom, on the side of each of the graduated cylinders and insert the connectors in the holes.
2. Connect the two cylinders with the small tubing and place the cylinders on the table (see sketch on right).
3. Pour colored water in the larger cylinder and note the water levels in each of the cylinders (make sure there are no bubbles in the connecting tube by lifting one cylinder up higher).
4. Now lift the smaller cylinder (A) so high that half of the liquid runs out (water level drops back to half of what it first was).



How do the movements of the cylinders themselves compare with each other?

**What to ask:**

1. Measure the distances (heights) lifted in each of the cases. Which of the cylinders had to be moved higher in order to let the same volume of water run out of the cylinder?
2. What did you notice about the water levels in each of the cylinders? If they were connected with a straight line, what kind of a line would it be? (slanted or horizontal?)
3. What did you notice about the volume of water diminishing in one cylinder and that increasing in the other? (let's say 50 ml runs out of the smaller one, by how much is the other increasing?)
4. In what ways can we make one water level stay higher than the other?
5. What would you predict if one cylinder was stoppered off before the other cylinder is raised or lowered? What would the water levels do?

**How to explain it:**

This would be a good demonstration to assess the understanding of the **law of communicating vessels** (after having done the two former activities). The two cylinders can be considered to be the legs of a U-tube. No matter how wide the diameter of one of the cylinders, the water levels always stay at the same height (level/horizontal), because the **pressure** (atmospheric) on the **meniscus** is the same. If one leg is closed off, a lower or higher pressure results from lowering or raising the other leg and the water level in the cylinder being raised will only drop very slightly, and thus the other water level will move up slightly too. When unstoppered, moving the smaller cylinder up 10 cm will probably increase the water level in the larger cylinder with 2 cm (depending on the ratio of the cylinders (practical application: **hydraulic lifts**)).

In the hydraulic lift oil is being used to lift a heavy object (on the wide cylinder) with a relatively small force on the narrower cylinder. By moving the plunger in the narrow cylinder over a longer distance (with a smaller force), a much heavier object can be lifted in the wider cylinder over a much shorter distance. By doing this repeatedly (where oil comes from a large reservoir), a heavy weight like that of a car, can be lifted.

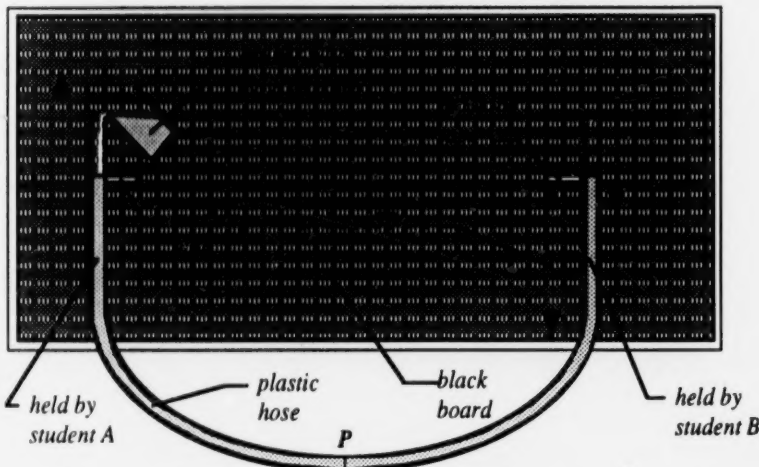


1.4.47. THE PLASTIC TUBING WATER LEVEL

**What you need:** 1. A clear plastic hose or tubing (at least 1 m long) 2. A long carpenter's level.  
3. A small beaker. 4. Food coloring.

**How to do it:**

1. Ask two students to hold each end of the tubing vertically so it forms a U-shape.
2. Pour some colored water (colored with the food coloring) into one of the tubing's end until there is at least 30 cm in each of the legs (see sketch).
3. Have the students hold the tubing against the board or wall, and mark the water levels (with chalk or tape on the board or wall).
4. Have students predict what will happen to the water levels if only student A is pulling his end of the tube higher!
5. Now let student A pull his end of the tubing 10 cm higher. What happened to the water levels? Mark them on the wall.
6. Have student B bring his end of the tubing 10 cm lower. What happened to the water levels? Mark them on the wall.
7. Connect the two marks on the board or wall with a straight line and use the carpenter's level to see whether the line is level.



**What to ask:**

1. Is the connecting line between the two marks level?
2. With how many cm did water level A go up, after student A pulled his end of the tubing 10 cm higher?
3. With how many cm did water level B go down, after student B brought his end of the tubing 10 cm lower?
4. If we connected the two marks (after A pulled it higher), what kind of line did we get? How was your prediction?
5. What would happen to the water levels if we had a bubble of air in the tubing? Try it!
6. What would the water levels do if we held the tube legs slanted? Or curved? Try it!

**How to explain it:**

This demonstration is illustrating the **law of communicating vessels** or tubes. No matter whether one leg of the tubing is pulled higher or brought lower, **the water levels in both legs always stay level**. Even when the legs are held slanted or curved, the water surfaces stay level. This is because the pressure on the left of point P has to stay equal to the pressure on the right of point P. See Sketch above.

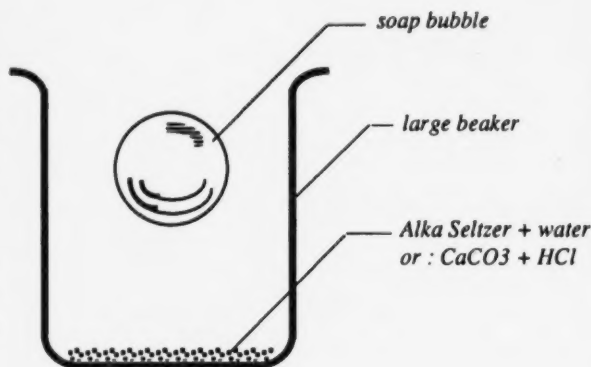
When moving the end of the tubing up on one end (say 10 cm), the water level is going up in both legs the same height, thus it is divided by two: up with 5 cm. When going down with one

1.4.48. **THE FLOATING SOAP BUBBLE**

- What you need:**
1. Soap solution (1 part Joy detergent, 2 parts glycerine, 3 parts water).
  2. A large beaker (2 liter) or clear plastic/glass container).
  3. Calcium carbonate or baking soda + dilute HCl; or Alka Seltzer tablets.
  4. A large plastic straw, and a small cup.

**How to do it:**

1. Pour the soap solution in the cup and get ready to blow a medium size bubble with the straw. Put a scoop of calcium carbonate/baking soda in the large beaker and add about 50 ml dilute hydrochloric acid; or one or two Alka Seltzer tablets plus some water.
3. Blow a medium size soap bubble (smaller than the beaker's diameter) and let it calmly fall in the large beaker (either guide it into the beaker or move the beaker to catch the bubble).
4. Observe the soap bubble (this demonstration/activity should be performed in a draft-free room).



**What to ask:**

1. What is being produced in the large beaker? (When using  $\text{CaCO}_3$  and HCl)?
2. Why did the soap bubble float above the liquid in the large beaker and not descend all the way to the bottom?
3. How does the density of carbondioxide gas compare with that of atmospheric air?
4. What other gas could be used instead of carbondioxide?

**How to explain it:**

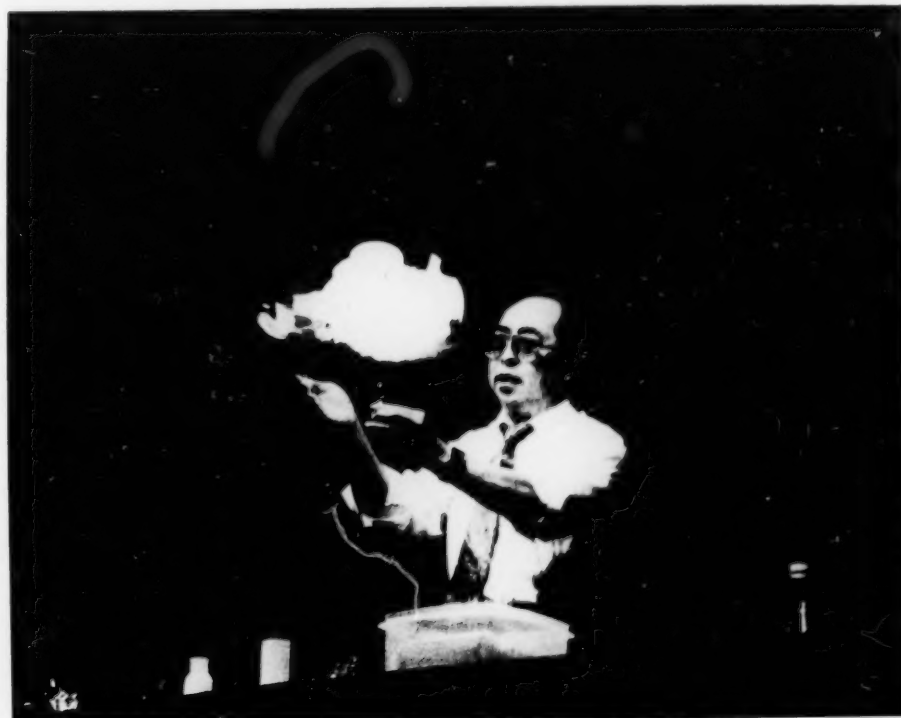
The chemicals, calcium carbonate or baking soda plus the dilute hydrochloric acid produce carbondioxide gas in the large beaker. This gas has a **larger density** (in other words is heavier) than air, and therefore stays in the beaker. The concentration of this gas is most likely higher closer to the surface of the liquid or bottom of the beaker.

The **density of a soap bubble is just slightly greater than that of air**. This is why bubbles ever so slowly descend in the air. In the large beaker the denser carbondioxide gas acts like a cushion, and this is why the bubble is not dropping all the way to the bottom.

The easiest source of carbondioxide gas is one or two tablets of Alka Seltzer in a little bit of water. Baking soda and a little vinegar in the bottom of the beaker will also do to create carbondioxide gas.

***Chemicals are dangerous  
but also lots of fun !***

Use **CAUTION** when dealing with **flammables !**



***Showing the total-combustibility of Lycopodium Powder.***

## CHAPTER 5

### HOW DO CHEMICALS BEHAVE IN OUR DAILY LIFE ?

**After dealing with and studying the concepts and sub-concepts of this chapter, the students should be able to:**

- a. Recognize the correct explanation of an observed event based on each of the sub-concepts;
- b. Explain in their own words which of the sub-concepts is determining the course of an event;
- c. Distinguish true from false statements concerning each one of the sub-concepts;
- d. Identify the correct explanation of an event in daily life applying one of the sub-concepts;

**all in relation to the following sub-concepts:**

- The existence of physical versus chemical changes.
- Different indicators will give different colors in acids and in bases.
- Some reactions produce gas, some produce precipitates.
- The solubility of chemicals in water differ greatly.
- Replacement and catalytic reactions.
- Exothermic, endothermic, and spontaneous combustion reactions.
- Addition reactions with unsaturated double bonds.
- Polymerization or formation of large molecules.

## 1.5.01. THE CHARCOAL SAUSAGE

- What you need:**
1. About 100 ml of table sugar crystals or powder.
  2. Two 100 ml beakers/small glass cups, two glass stirrers.
  3. Concentrated sulfuric acid ( $\text{H}_2\text{SO}_4$ ) or liquid drain opener (sulfuric acid kind).



**CAUTION:**  
DO NOT GET SULFURIC ACID  
ON YOUR FINGERS OR ANY  
OF YOUR CLOTHING!

**How to do it:**

1. Fill each beaker half full with sugar.
2. Add about 40 ml of water to the first beaker and the same amount of concentrated sulfuric acid to the second beaker; stir and let stand (stand back, wear protective gloves!).
3. Observe the difference between the two changes in the sugar. Ask: "In which beaker do the reactants still have the same properties?" (The reaction should preferably be carried out under a fume hood or close to an open window, or in the outdoors).

**What to ask:**

1. What is the difference between the processes in beaker I and II?
2. How can we recognize or distinguish between a physical change and a chemical change?
3. In which of the two beakers could we get the sugar back as sugar?
4. What do you think happened in the second beaker?
5. What property do you think concentrated sulfuric acid has?
6. What do you think the black material in beaker two is?

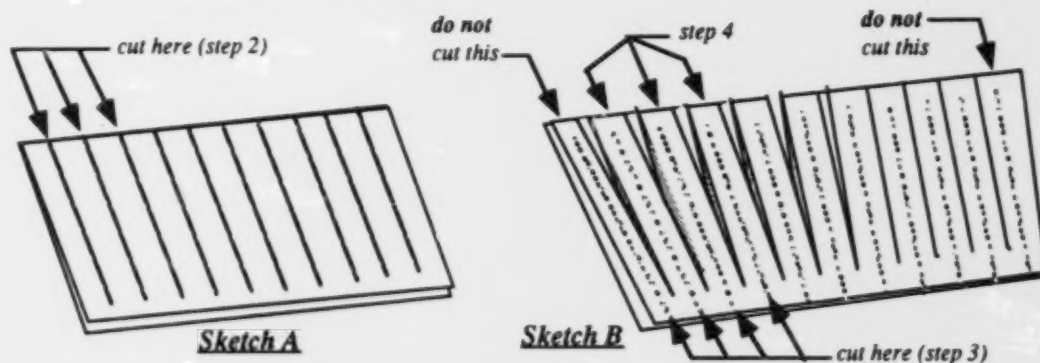
**How to explain it:**

In beaker I, where the sugar was mixed with the water, a physical change was taking place. This means that the components of the mixture retained their properties; they could be separated and still have the **exact properties as before the change**. The water could be left to evaporate and the sugar would crystallize out of the solution. In beaker II a chemical change took place, leaving products, which have **properties that are completely different** from the original components of the mixture. A black charcoal mass is produced, which is expanding up because of the gases ( $\text{CO}_2$ ) and water vapor being released. This is caused by the **dehydrating** (taking water out) properties of concentrated sulfuric acid.



## 1.5.02. WALK THROUGH A HOLE IN ORDINARY NOTEBOOK PAPER

**What you need:** 1. One sheet of ordinary notebook paper.  
2. A pair of large, sharp scissors.

**How to do it:**

1. Tell the students that you are going to cut a hole in the ordinary piece of paper, and that you are going to walk right through the hole without tearing the paper!
2. Fold the paper in half, then make a series of straight cuts from the folded side, about 2 cm apart stopping about 1 cm from the edge of the opposite side (see Sketch A).
3. Turn the paper around and make cuts from the other side (see dotted lines in Sketch B), and also stop about 1 cm from the edge of the opposite side.
4. Except for the first and last strip at each end, now snip off the folded ends of the strips.
5. Then carefully open up the paper without tearing anything and walk through the hole!

**What to ask:**

1. Do you think you could ride a bicycle through the hole?
2. We've changed the paper by cutting it; was it a physical or chemical change that the paper underwent?
3. Did we change any of the chemical properties of the paper?
4. What is the difference between a physical change and a chemical change in a sample of matter?
5. What are some other ways that you could make a physical change in this piece of paper?
6. What are some ways that you could make a chemical change in the paper?

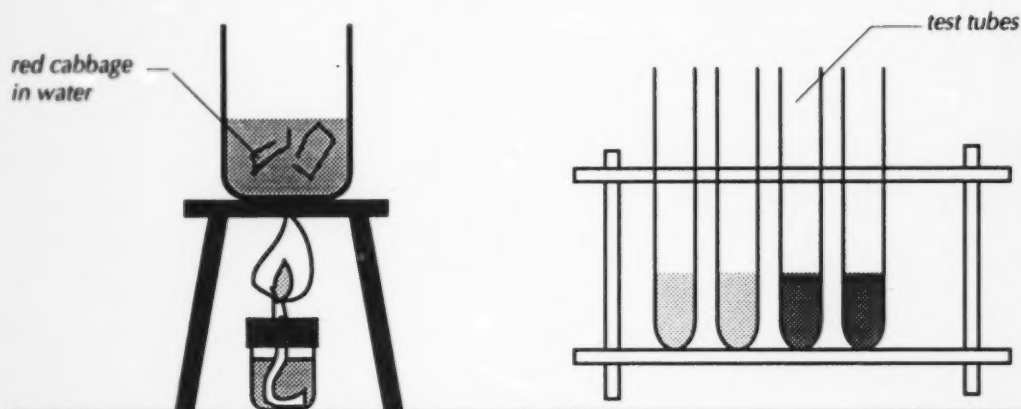
**How to explain it:**

Of course, the change that we made in the paper was a physical one. No chemical properties of the paper were changed, before or after the change. When a **chemical change** is occurring in a sample of matter, the **chemical properties** in the products after the change are **completely different** from those before the change. To make a chemical change in the paper, it could be burned or placed in sulfuric acid. The products of the burning process of paper would be  $\text{CO}_2$  (carbondioxide) which is a gas, plus water vapor and carbon. All three products having totally different properties compared to those of paper (the sample of matter before the change).

Other physical changes are: the dissolving of salt or sugar in water, the stretching of a rubber band, the cutting of an apple (but as soon as the apple cuttings are exposed to the air, a chemical change takes place: browning), etc.

## 1.5.03. THE BLUE AND RED CABBAGE

- What you need:**
1. A few leaves of red cabbage.
  2. A small beaker (or glass tea pot) and four test tubes (+test tube rack if available).
  3. An alcohol burner and stand/stove top.
  4. Vinegar, lemon juice, baking soda, lime.

**How to do it:**

1. Cut a red cabbage leaf in small pieces; place it in the beaker/tea pot and add about 10 ml of water to it.
2. Heat it above the burner/stove top until boiling, then pour equal amounts of the liquid in the four test tubes.
3. Place a few drops of vinegar in the first and a few drops of lemon juice in the second test tube: have students observe closely the color of the liquid.
4. Now add a pinch of baking soda to the third and a pinch of lime to the fourth test tube: observe the color change!

**What to ask:**

1. Which two chemicals colored the cabbage juice red?
2. Which two colored the cabbage juice blue?
3. What would happen if we added baking soda to the cabbage leaf?
4. To which of the two groups of chemicals would orange juice belong? Pineapple juice? Grape juice? Soap water?
5. What would happen if we added vinegar to the blue liquid?

**How to explain it:**

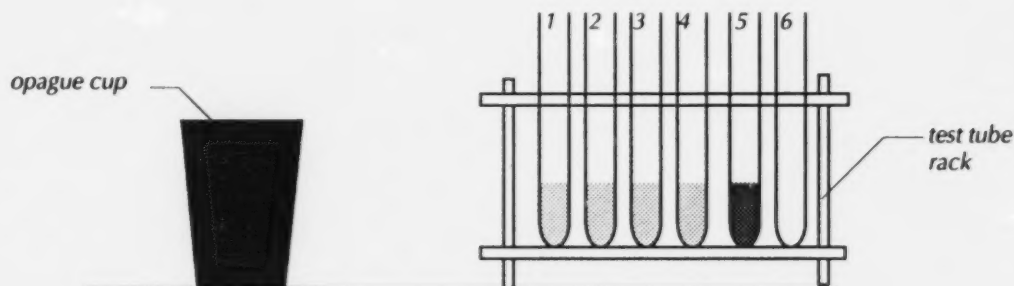
The red cabbage juice acts like litmus, an **indicator** that turns red in acids and blue in bases. Vinegar, lemon juice, and other **sour tasting** juices are all **acids**; whereas baking soda, lime, and soap water are **bases**. Chemists are talking in terms of pH (which will be dealt with in higher grades: the negative logarithm of the hydrogen ion concentration). A pH of 7 for a neutral liquid, less than 7 for acids, and higher than 7 (up to 12) for bases.

Other common indicators are: litmus paper, phenolphthalein, methyl orange, methyl red, universal indicator, etc.

## 1.5.04. THE FUNNY COLORS

**What you need:** 1. A test tube rack with six test tubes.

2. Dilute hydrochloric acid (HCl). (1 Normal)
3. Dilute sodium hydroxide solution (NaOH). (1 Normal)
4. Phenolphthalein indicator (*Alophen or Exlax powder in alcohol*), \* and a drinking straw.
5. Medicine dropper, an opaque cup (styrofoam will do)



**How to do it:**

1. Number the six test tubes to avoid confusion.
2. Tape a white paper behind the tube rack for easier distinction of the pink color in the test tubes (a spot light will help).
3. Place 3 drops of phenolphthalein (or *Exlax solution*) in test tube No. 2 and 4; and 1 drop of NaOH in test tube No. 6 and the cup each; and 3 drops of HCl in test tube No. 5.
4. Fill the opaque cup with drinking water from a pitcher, then halfway fill test tube 1, 2, 3, & 4 from the cup (2 & 4 appear pink).
5. Say: "There must be something wrong!" Pour the four test tube contents back into the cup. Now fill test tubes 1, 2, 3, 4, & 5. (All are pink except for No. 5).
6. Say: "What now?" Pour all 5 tubes back and fill all six tubes. No. 6 stays pink. Blow color away with the straw!

**What to ask:**

1. What made the pink color in test tube No. 2 and 4?
2. What made the color disappear in test tube No. 5?
3. What is in our breath that can neutralize the basic solution?
4. What else could we use to take away that pink color of tube 6?

**How to explain it:**

Phenolphthalein (or *Exlax solution in alcohol*)\* is an **indicator** for basic solutions. It turns pinkish red in dilute sodium hydroxide solution or any other basic solution (with a pH higher than 7). Test tube 5 contains hydrochloric acid, which will neutralize the base being poured in it. The pH is brought back to lower than 7 and thus turning the liquid colorless.

The air that human beings are exhaling contains more carbon dioxide than atmospheric air. This gas is slightly acid in water and neutralizes the weak basic solution. Other substances that can be used to neutralize bases are: vinegar (acetic acid), lemon juice (citric acid), etc.

\* Andy Sae - "Chemical Magic from the Grocery Store", 1991, Portales, NM 88130

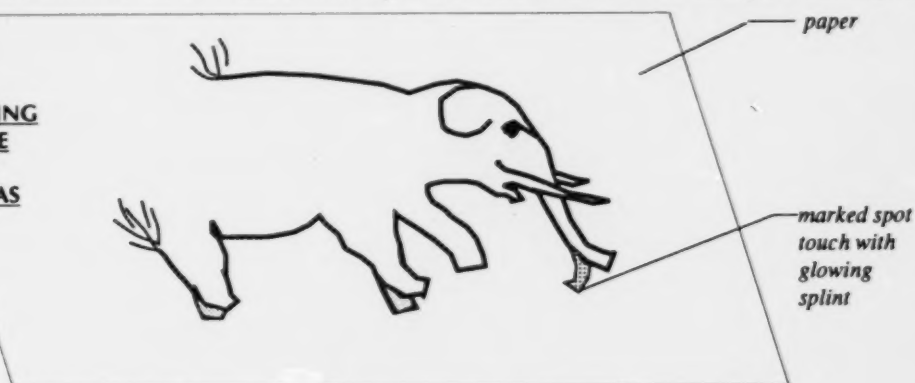


## 1.5.05. DRAW WITH FIRE

**What you need:** 1. Potassium or sodium nitrate (saltpeter). 2. A small beaker and a glass stirring rod.

**CAUTION:**

**BEFORE DISPOSING  
THE PAPER, MAKE  
SURE THAT THE  
SMOLDERING HAS  
COMPLETELY  
STOPPED !**

**How to do it:**

1. Dissolve a full scoop of potassium nitrate (or sodium nitrate) in about 20 ml of water in the beaker, and stir with the glass rod until all the solid material dissolved.
2. Keep adding another scoop of  $\text{KNO}_3$  or  $\text{NaNO}_3$ , and stir until the solid material stays as a solid on the bottom of the beaker.
3. Take a blank sheet of paper and draw an animal or other object on the paper with the glass rod dipped in the saturated solution. (make the lines rather thick and use the liquid rather liberally).
4. Leave the paper to dry at room temperature. Before it is completely dry, mark one spot where the drawing was started with a pencil.
5. Show the students the completely blank sheet of paper, and tell them that you will start a drawing on the paper with fire! Strike a match, blow it out, and with the glowing tip touch the marked spot on the paper; observe!

**What to ask:**

1. Why does the pencil mark have to be made just before the drawing was completely dry?
2. What made the glowing continue further on the paper?
3. Was it actually a flame that made the drawing?
4. What kind of a reaction was it: endothermic or exothermic?
5. Is this type of a reaction a spontaneous reaction?
6. What was the glowing wood tip initially needed for?

**How to explain it:**

Potassium or sodium nitrate is a strong oxidant. After the water of the saturated solution evaporated, there was only potassium nitrate left on the paper in a very finely divided state. The glowing tip of the match supplied the initial **activation energy** needed to release very active oxygen from the potassium nitrate. This active oxygen is further oxydizing the paper (seen in the form of a burning glow), which is **exothermic** (giving off heat). This energy is enough to keep further releasing the oxygen from the  $\text{KNO}_3$ . Since this is only found on the line of the drawing, the glow of the paper burn is only following the path of the drawing.

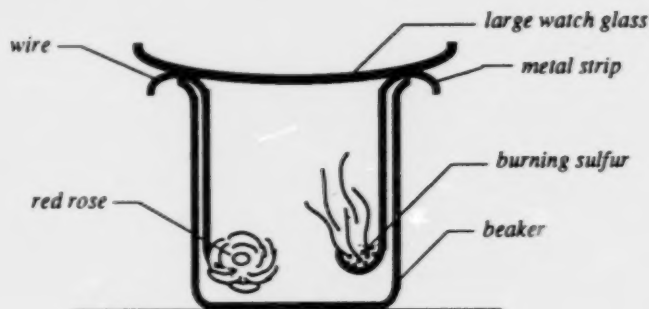


1.5.06. **TURN A RED ROSE INTO A WHITE ONE**

**What you need:** 1. A small red rose, and sulfur powder (S).  
2. A short metal strip, and a short metal wire.  
3. A glass beaker/drinking glass and a watchglass/saucer to cover it.

**CAUTION:**

**SULFUR DIOXIDE GAS  
IS VERY PUNGENT  
AND POISONOUS!**

**How to do it:**

1. Attach the wire to the stem of the rose and let it hang inside the beaker from the rim (make a hook in the wire).
2. Bend the short metal strip in an S-shape so that it can hang from the rim of the beaker (hang this on the opposite side: see Sketch above).
3. Take this metal strip out of the beaker and place a small heap of sulfur powder on the bent part of the metal strip, hold a lit match close to the sulfur until it catches fire. Immediately lower the metal strip into the beaker and cover it with the watchglass/saucer. Observe! (Keep the beaker covered; it would be best to perform this under the fumehood or outdoors).

**What to ask:**

1. What color did the red rose turn into?
2. What part of the rose started to change color first?
3. What type of reaction is actually taking place?
4. What gas was formed by burning the sulfur?
5. What other bleaching agents do you know?
6. What is the function of the watchglass/saucer over the beaker?

**How to explain it:**

By burning the sulfur, sulfurdioxide gas is formed ( $\text{SO}_2$ ) which is a strong **reductor**. The red coloring in the rose is being reduced and turns white. Sulfurdioxide is a very pungent gas and also poisonous when inhaled in large doses. This is why it is very important to dispose of the fumes under an exhaust hood or outdoors.

Other bleaching agents are chlorine compounds, like: chloride of lime, sodium chlorite, sodium hypochlorite (used in laundry bleaches) and calcium hypochlorite. In solution, these agents release chlorine gas, which reacts with color molecules and thus also remove color. The sulfurdioxide gas plus the water in the rose petals form sulfurous acid, which works as a reducing agent. The reaction with the water is as follows:  $\text{SO}_2 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{SO}_3$

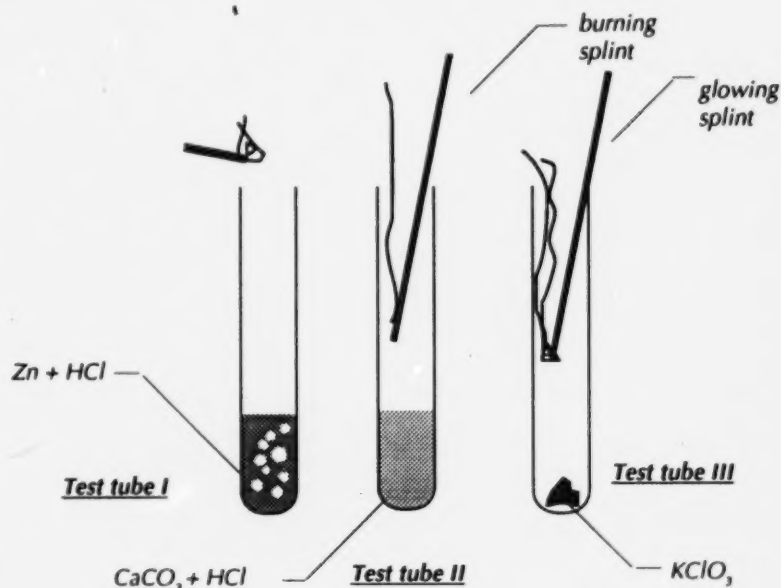


## 1.5.07. WHICH GAS IS WHICH ?

**What you need:** 1. Zinc powder or chips (galvanized iron), calcium carbonate (marble chips), potassium chlorate -  $\text{KClO}_3$ , and hydrochloric acid -  $\text{HCl}$ (dilute).  
2. An alcohol burner and wood splints. 3. Three test tubes.

**How to do it:**

1. Place a few zinc chips in the first test tube, add about 3 ml of dilute  $\text{HCl}$ , and place your thumb over the tube. Light a match and bring it close to the test tube's mouth: release thumb! release thumb!
2. In the second test tube, put a few marble chips and add about 3 ml of dilute  $\text{HCl}$ . Burn a wood splint and lower the flame into the test tube. (What happens to the flame?)
3. Put a little  $\text{KClO}_3$  plus a little of the burnt ashes from the wood splint into the third test tube. Mix them by shaking the tube and heat it slowly over the alcohol flame. Test the gas with a glowing wood splint (not a burning one; flame should be blown off before inserting in tube).

**What to ask:**

1. What gas is produced in the first test tube?
2. What unique characteristics does this gas possess?
3. What gas is produced in the second test tube?
4. How can we recognize this second gas from the others?
5. What gas is produced in the third test tube?
6. How different is this third gas compared to the other two?

**How to explain it:**

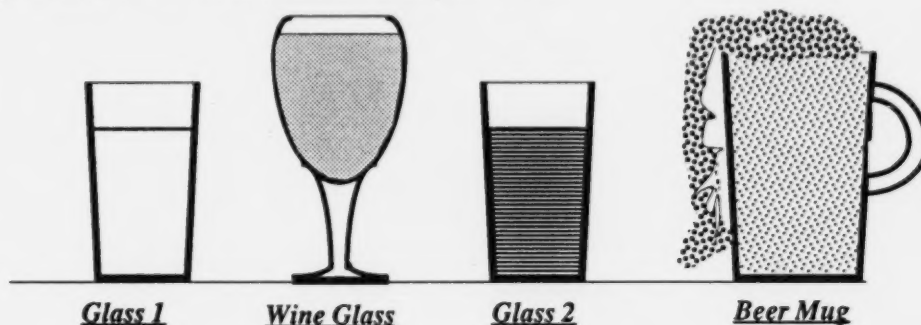
In test tube I:  $\text{Zn} + 2 \text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$ ; Zinc chloride and hydrogen gas is produced. This gas is highly flammable and gives off a characteristic small explosion, when ignited in the test tube.

In test tube II:  $\text{CaCO}_3 + 2 \text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$ ; calcium chloride, water, and carbon dioxide are formed. This gas is also invisible, but it has the property of extinguishing a flame.

In test tube III:  $2 \text{KClO}_3 \rightarrow 2 \text{KCl} + 3 \text{O}_2$ ; potassium chlorate is decomposed by heat into potassium chloride and oxygen gas, which makes a glowing splint flare up. Oxygen is present in the air and makes up 20% of the atmospheric air: a necessary component for all living things.

1.5.08. **TURN WATER INTO WINE, MILK, AND BEER !**

- What you need:** 1. Sodium bicarbonate ( $\text{NaHCO}_3$ ), sodium carbonate ( $\text{Na}_2\text{CO}_3$ )  
2. Phenolphthalein (Exlax in alcohol)\*, saturated barium chloride solution ( $\text{BaCl}_2$ )  
3. Two drink glasses, a wine glass, a beer mug.  
4. Conc. Hydrochloric acid -  $\text{HCl}$ , and Bromothymol Blue.

**How to do it:**

1. Fill glass No. 1 three-quarters full of water and add 10 ml of saturated  $\text{NaHCO}_3$  and 20%  $\text{Na}_2\text{CO}_3$  solution (pH 9).
2. To the wine glass add a few drops of phenolphthalein/Exlax solution.
3. To glass No. 2 add about 25 ml of saturated  $\text{BaCl}_2$  solution.
4. To the beer mug add 5 ml of conc.  $\text{HCl}$  and about 3 ml of bromothymol blue. (Points 1-4 should be done without the students knowing). Now you are ready for the demonstration: Starting with glass No. 1, tell the class/audience that you have water in the glass; then pour contents into the wine glass while saying: "Now I am turning it into wine!" Now pick the wine glass up and pour contents into glass No. 2, saying: "Then I am turning it into milk!" Pick this glass with "milk" up and pour its contents into the beer mug, while saying: "Now the milk turns into beer!"

**What to ask:**

1. What made the colorless solution turn red in the wine glass?
2. What chemicals would produce a white precipitate?
3. What reaction would produce a gas?
4. Could we turn the beer back into milk?
5. What is a one-way reaction like the above one called?
6. What reversible reactions do you know?

**How to explain it:**

The change of the colorless liquid in glass No. 1 into the red colored solution in the wine glass is caused by the phenolphthalein, which turns red in basic solutions. The barium ions in glass No. 2 precipitated out in the presence of carbonate ions from the  $\text{Na}_2\text{CO}_3$ , and thus gave the milky white appearance. This milky mixture is actually a suspension of  $\text{BaCO}_3$  solid particles in water. Pouring this suspension into the concentrated hydrochloric acid and bromothymol blue produces  $\text{CO}_2$  gas throughout the liquid, thus forming the foam like in a beer. The bromothymol blue gave it the yellow color at that particular pH.

This demonstration would be most effective if steps 1 through 4 were not shown to the students!

## 1.5.09.

## MAKE A SMOKE SCREEN

**What you need:** 1. Two wide (large size) test tubes.

2. Four L-shaped glass tubes in two 2-hole stoppers.

3. A T-tube and two pieces of rubber tubing or instead of 1-3: two drinking glasses.

4. Concentrated HCl and ammonia ( $\text{NH}_4\text{OH}$ ).

**How to do it:**

1. Fit the four L-tubes in the two 2-hole stoppers as in Sketch A.

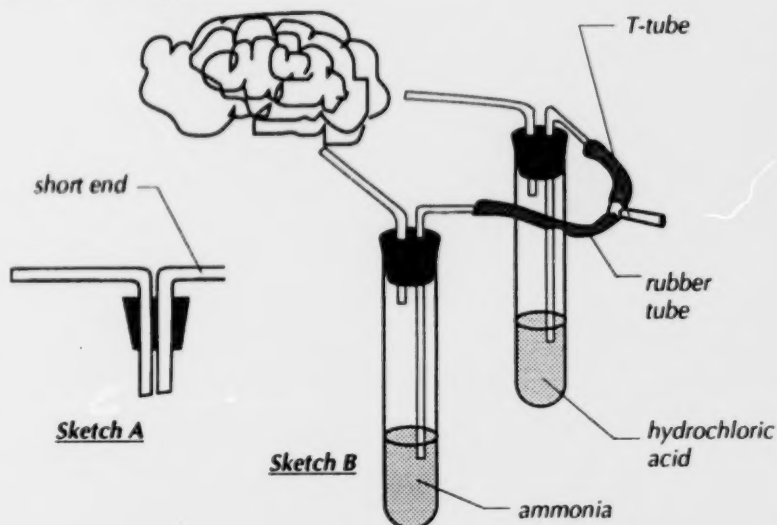
2. Attach two rubber tubes to the short ends of the L-tubes above the rubber stopper (see Sketch A).

3. Attach the other end of the two rubber tubes to the glass T-tube (see Sketch B).

4. Place about 10 ml of concentrated hydrochloric acid (HCl) in one test tube and 10 ml of concentrated ammonia ( $\text{NH}_4\text{OH}$ ) in the other; or if working with the two drinking glasses, place 10 ml of HCl in one and 10 ml of  $\text{NH}_4\text{OH}$  in the other glass.

5. Close the test tubes off with the stoppers (and tubes in them).

6. Hold the two test tubes in one hand (making sure that the two free ends of the glass tubes are close together), hold the T-tube in the other hand, and blow through the free end of the T-tube; or hold the two glass mouths close together, and observe !.

**What to ask:**

1. What reaction is taking place?

2. What is making up the smoke particles?

3. How could we do this reaction without the glass and rubber tubes?

4. What does smoke in general consist of?

**How to explain it:**

The reaction that takes place where the smoke is formed, is as follows:

$\text{NH}_4\text{OH} + \text{HCl} \rightarrow \text{NH}_4\text{Cl} + \text{H}_2\text{O}$ . The  $\text{NH}_4\text{Cl}$  (ammonium chloride) is a **solid** and as the reactants are gases or actually fine mists, the ammonium chloride formation results in very fine solid particles. **Smoke** is exactly this: a **fine suspension of solid particles** in a gas. Smoke that is used for sky-writing by planes, is produced by spraying special oils and paraffins on the hot exhaust of the airplane.

If glass and rubber tubes are not available, the reaction can also be accomplished by holding the mouths of the two test tubes or drinking glasses with HCl and  $\text{NH}_4\text{OH}$  close to each other.

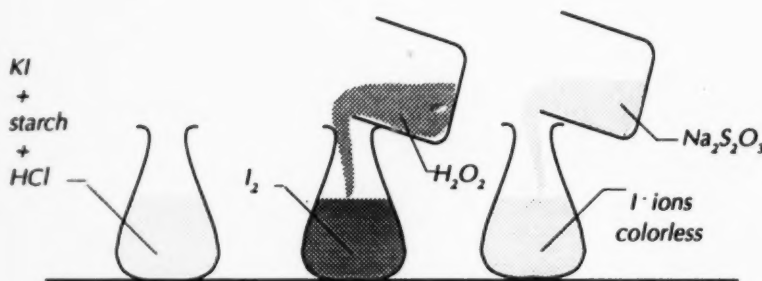
## 1.5.10. THE RETURNING COLOR

**What you need:** 1. One Erlenmeyer flask/clear glass bottle (medium size), & two beakers.

2. Potassium iodide (KI), hydrogen peroxide ( $\text{H}_2\text{O}_2$ ), sodium thiosulfate ( $\text{Na}_2\text{S}_2\text{O}_3$ ), starch solution, and dilute hydrochloric acid (HCl).

**How to do it:**

1. Dissolve a little KI in water, add some starch solution and a little dilute HCl (Sketch A).



2. Prepare solutions in beaker B and C.

Place a 3%  $\text{H}_2\text{O}_2$  solution in beaker B; dissolve some sodium thiosulfate in about 100 ml of water in beaker C.

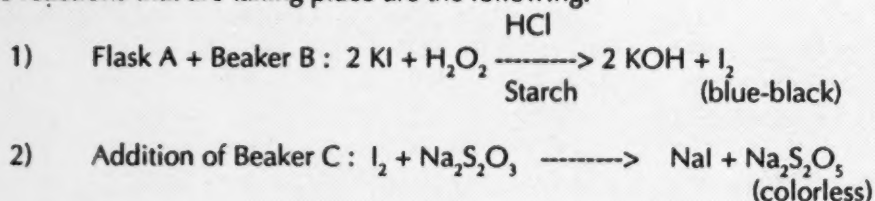
3. Add to flask A some of liquid B (turns blue-black) and immediately afterwards a little of liquid C (turns colorless).
4. Place flask on table and observe: sudden color change!
5. The addition of liquid C can be repeated several times. (To make it more interesting, after addition of liquid C, hold the flask behind your back for a few moments and bring it back on the table as a blue-black solution).

**What to ask:**

1. How is the blue-black color created?
2. What was it that took away the color?
3. Which reaction is slower? The color-producing or the color-removing one?
4. How long can we keep repeating the second reaction?
5. What reactions are usually slower in rate?

**How to explain it:**

The reactions that are taking place are the following:



Reaction (1) is an **oxidizing** reaction, where the iodide ions are oxidized into iodine, which turns starch into a blue-black color. The addition of  $\text{Na}_2\text{S}_2\text{O}_3$  **reduces** the iodine back into iodide ions, which are colorless. The fact that the blue-black color keeps on returning, even after the  $\text{Na}_2\text{S}_2\text{O}_3$  is added, shows that the first reaction is still proceeding and thus is a much **slower** reaction than the second.

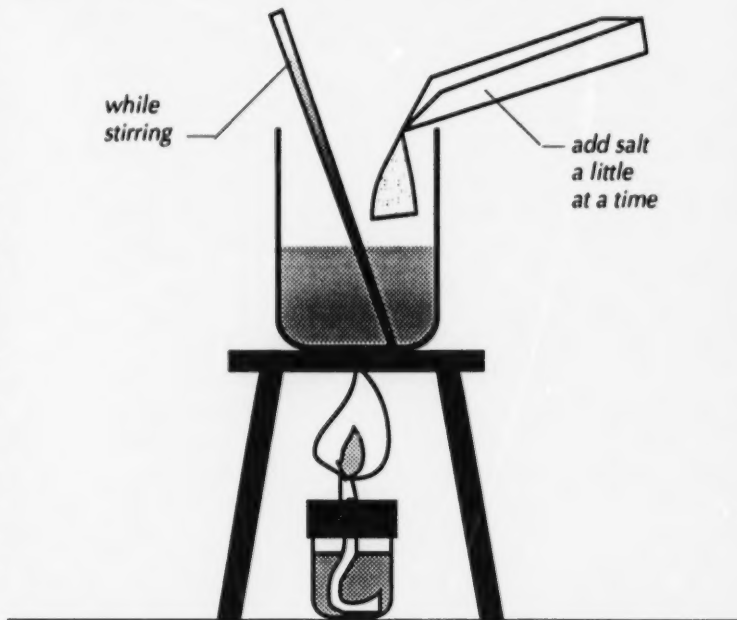


1.5.11. **DISSOLVE MORE SALT BY COOLING ?**

**What you need:** 1. Sodium nitrate, sodium chloride or table salt ( $\text{NaCl}$ ), potassium nitrate ( $\text{KNO}_3$ ), potassium chloride, calcium acetate.  
 2. Three beakers (250 ml), stirrers, & scoop. 3. Alcohol burner & stand.

**How to do it:**

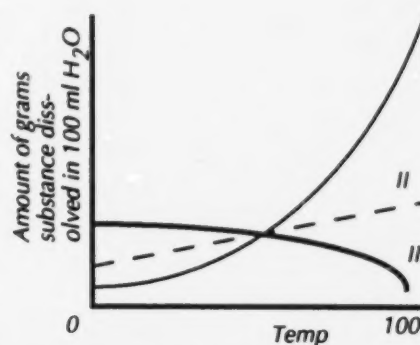
1. Make a saturated solution of each of the following salts: potassium nitrate (or sodium nitrate or potassium chloride), sodium chloride, and calcium acetate, at room temperature, by adding half a teaspoon at a time to 100 ml of water, until some solid is left behind after stirring for one minute. (Stir after every addition of solid).
2. Now heat beaker I (with  $\text{KNO}_3$ ) and as soon as the solid particles dissolve, add half teaspoon at a time until some solid stays undissolved.
3. Do the same with beaker II (with  $\text{NaCl}$ ): not as much can be dissolved! 4. Heat beaker III (with Ca- acetate): more solid precipitates out!

**What to ask:**

1. How could we dissolve more Ca acetate in Beaker III?
2. Most salts behave like the first two salts; what variable goes up with increasing temperature?
3. Which of the salts could dissolve much more with increasing temperatures?
4. What happened to the three salt solutions after being cooled?

**How to explain it:**

The **solubility** of a substance is generally increased with increasing temperatures (see solubility curves I and II on the right). Solubility curve III is very seldom encountered. Students can keep track of the amount of salt added to the water and the temperature, in order to plot a **solubility curve**.

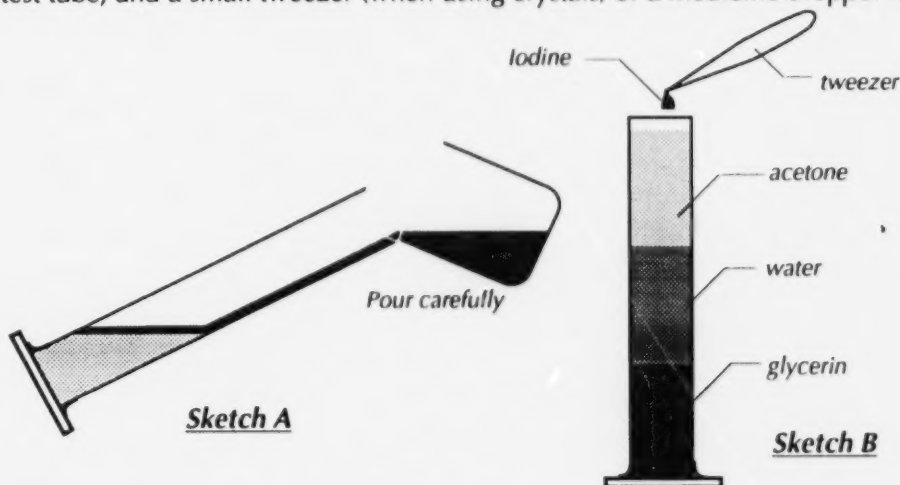




## 1.5.12. THE THREE-LAYERED LIQUID

**What you need:** 1. Glycerin, acetone (nail polish cleaner).

2. Iodine crystals or iodine tincture, or potassium permanganate crystals ( $\text{KMnO}_4$ ).
3. A test tube, and a small tweezer (when using crystals) or a medicine dropper for iodine.

**How to do it:**

1. Pour about 1/3 of the test tube length of glycerin in the test tube.
2. Carefully pour another 1/3 test tube length of water on top of the glycerin, by slanting the test tube when pouring (see Sketch A).
3. Do the same thing with another 1/3 test tube length of acetone on top of the water.
4. Hold the test tube vertically and drop several crystals of iodine or potassium permanganate in the layered liquid. Observe the colors!

**What to ask:**

1. Why did the water float on top of the glycerin?
2. Would acetone be able to float on top of glycerin?
3. What does it depend on whether we can make layered liquids or not?
4. Why did we get different colors in the liquid?
5. What does a dark color indicate about the solubility of the solid in the liquid?
6. In what liquid did iodine dissolve the least or did permanganate dissolve the least?
7. With what other liquids could we make layers?

**How to explain it:**

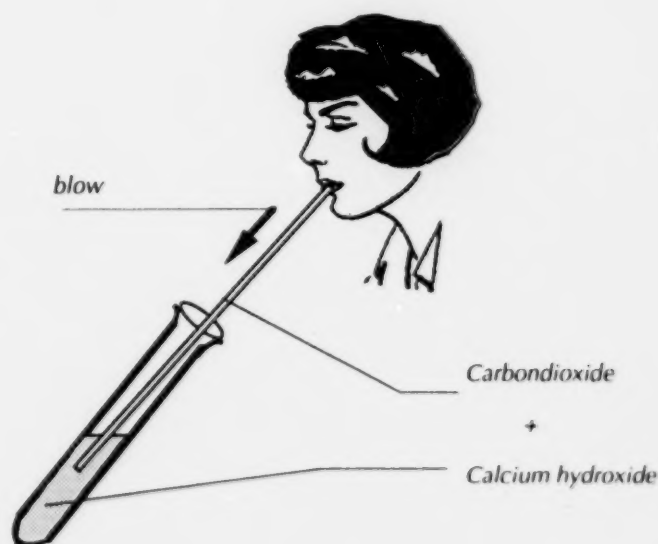
The liquids could stay layered on top of each other, firstly because one is lighter than the other (smaller in density), and secondly because they are **insoluble/immiscible** in each other: the glycerin is **partially immiscible** with water, and the acetone is also insoluble in water. Acetone is also **immiscible** in glycerin and thus floating the first into the other would also work. Most organic liquids, like oils, gasoline, benzene, etc. except alcohols, are **not soluble** in water or immiscible with water. The iodine crystal, when dropped through the layered liquid, dissolves in different degrees in each of the solvents. This is why different color intensities appear in the liquid layers.

## 1.5.13.. THE DISAPPEARING PRECIPITATE

**What you need:** 1. Calcium hydroxide solution —  $\text{Ca(OH)}_2$ .  
2. A wide test tube & a drinking straw.

**How to do it:**

1. Fill the test tube about one-third with calcium hydroxide solution. If in powder form, make a saturated solution by dissolving some in warm water and filtering excess powder; use filtrate.
2. Blow through the straw into the calcium hydroxide solution until a precipitate is formed (cloudy solution).
3. Now continue blowing into the cloudy liquid until the liquid clears up again. Say: "The cloud is blown away!"

**What to ask:**

1. What is the reaction that forms the precipitate?
2. In general, why and when is a precipitate formed?
3. What made the formed precipitate disappear?
4. When is a precipitate or solid powder in a liquid invisible?
5. Can you name other precipitous reactions?

**How to explain it:**

By blowing into the solution, we were adding carbon dioxide gas to it. The reaction is as follows:  $\text{CO}_2 + \text{Ca(OH)}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$ , where the calcium carbonate formed is the **precipitate**. Although this precipitate is in the form of a milky or cloudy substance, it is still a deposit of solid material. This is apparent when the blowing is ended at this stage and the test tube is left standing for a while. A precipitate will then collect at the bottom of the test tube.

By continuing the blowing, more carbon dioxide is added to the precipitate, resulting in the reaction:  $\text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{Ca(HCO}_3)_2$ , which is calcium bicarbonate, and this substance is soluble in water.

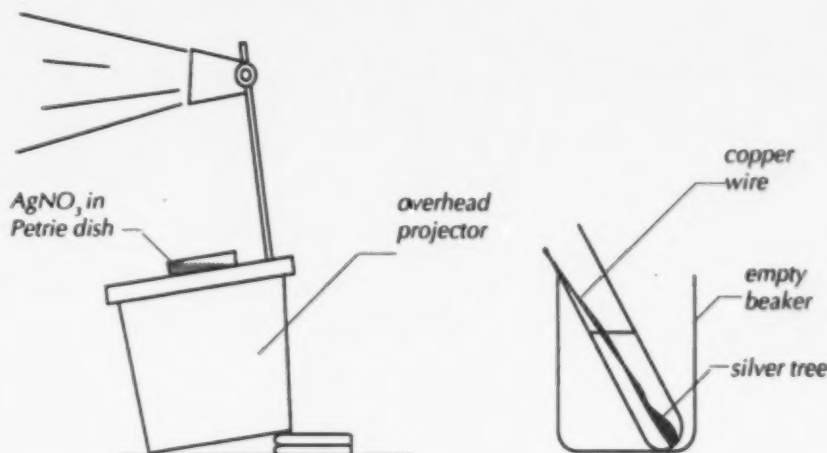
In general, a **precipitate** is formed when the compound formed has a **low solubility** in water. When this solubility is increased, either by raising the temperature or by changing the compound itself, it goes back into solution and becomes invisible (clear liquid).

1.5.14. **MAKE A SILVER TREE**

**What you need:** 1. A thick solid copper wire (about 10 cm long).  
2. Silver nitrate solution— $\text{AgNO}_3$ .  
3. A test tube or when available: petri dish & overhead projector.

**How to do it:**

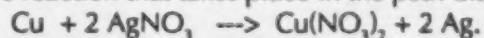
1. Strip the insulation off a heavy electric wire (with solid core).
2. Place about 10 ml of  $\text{AgNO}_3$  (silver nitrate) in a petri dish, or in the test tube (when dish & overhead projector are not available).
3. Put the dish on the overhead projector and slant the projector towards the screen by placing some books under the far end.
4. Place the copper wire in the dish, such that the projection shows up vertically on the screen (or insert the wire in the test tube).
5. Let students observe closely when doing the reaction in a test tube, but they may not jar or touch the test tube.

**What to ask:**

1. What did you observe on the screen or in the test tube?
2. What is the 'tree' composed of?
3. What specific reaction took place?
4. What would happen if the test tube were jarred or touched?
5. What caused the liquid to turn blue?

**How to explain it:**

The reaction that takes place in the petri dish or test tube is as follows:



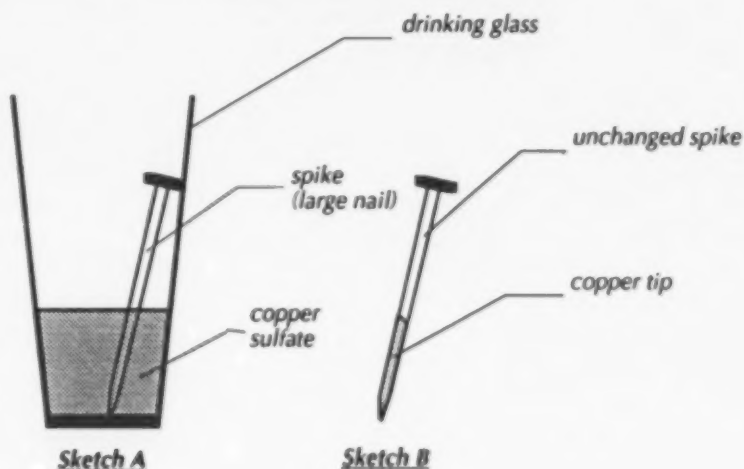
The silver **precipitates out** of the solution but clings to the copper wire, which gives the illusion of a growing tree. The reaction occurs because copper has a larger tendency to go into solution than silver. As the copper goes into solution, it forms copper ions, which are responsible for the blue color of the liquid. The longer the copper is left in the liquid, the more copper is going into solution, thus the more copper ions are formed and the deeper blue the liquid gets. The silver, which is deposited along the wire, is just hanging loosely on it and a very slight disturbance (jarring of the container) will send the silver branches crashing down.

## 1.5.15. THE COPPER TIP NAIL

**What you need:** 1. Dilute copper sulfate solution. 2. A steel wool sponge.  
3. A large iron nail/spike. 4. A drinking glass & plastic stirrer.

**How to do it:**

1. Place some copper sulfate crystals in the glass, add some water and stir with the plastic stirrer until all the solid has dissolved.
2. Place the large nail in the glass and let stand for a few minutes.
3. Now plunge the steel wool sponge in the glass and let it sit in the blue solution.
4. Take the nail out and observe the nail tip.
5. Also observe the steel wool and the color of the sulfate solution!

**What to ask:**

1. What made the blue color disappear in the sulfate solution?
2. What do you infer would be in the glass after it turned colorless?
3. What color did the nail tip and the steel wool turn into?
4. How could we make the blue color reappear in the sulfate solution?
5. What is actually responsible for the blue coloring?

**How to explain it:**

The **replacement reaction** during the plunging of the nail and the steel wool into the copper sulfate solution is as follows:  $\text{CuSO}_4 + \text{Fe} \rightarrow \text{FeSO}_4 + \text{Cu}$ . Copper sulfate + iron  $\rightarrow$  ferrous sulfate + copper. It is the replacement of the **copper ion** in the solution with ferrous ions that makes the solution colorless. This will only occur when there is enough iron to replace the copper ions or when enough time is given to do this replacement.

In order to get the blue color back, we need dilute hydrochloric acid. Then we get the following reaction:  $\text{Cu} + 2\text{HCl} \rightarrow \text{CuCl}_2 + \text{H}_2$ . The copper is transformed into the copper ion again and this ion is responsible for the blue color in the liquid.

The first reaction occurs because iron has a greater tendency to go into solution or to form ions compared to copper, thus iron replaces the copper ions and the solution becomes colorless, because the copper ion is transformed into the copper metal. The second reaction shows that the acid turns the copper metal back into copper ions: solution turns green.



## 1.5.16. THE GLOWING PENNY

**What you need:** 1. A penny or other copper coin.

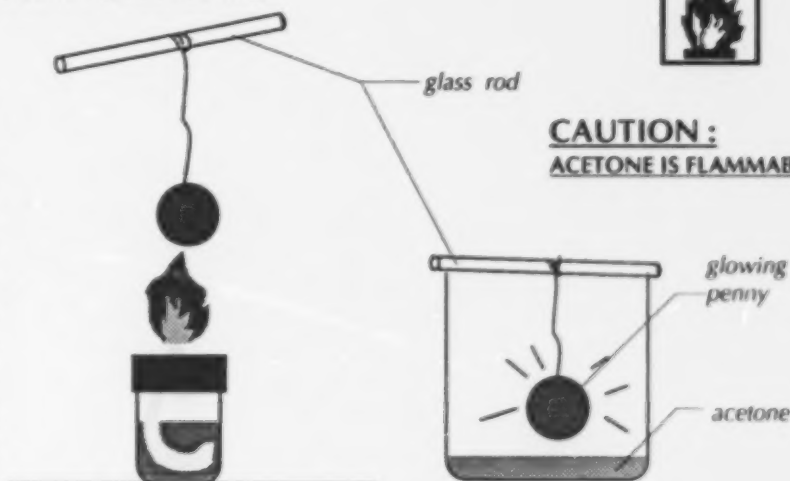
2. Copper or Nichrome or other thin metal wire.

3. A glass stirrer, small beaker/drinking glass, alcohol or propane burner.

4. Acetone/nail polish cleaner (about 20 ml).

**How to do it:**

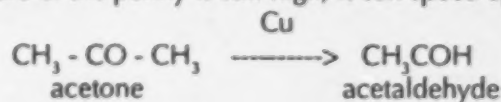
1. Make a small hole in a penny (punch a small nail through) and tie a short length of wire (about 10 cm) through the hole/ or wind the wire around the penny twice and tie it..
2. Wind the other end of the wire around the middle of a glass stirrer and heat the coin in an alcohol or propane flame until red hot (Sketch A).
3. Immediately after heating, hang the coin about 3 mm above the acetone level in a beaker/glass (check this level before heating the coin, by rolling more or less windings around the glass stirrer—see Sketch B).
4. Observe the glowing penny in the dark.

**What to ask:**

1. What made the penny glow in the flame?
2. What made the penny glow in the beaker?
3. Would the penny glow if it was hanging higher above the acetone level?
4. How high can the coin hang and still have it glowing?
5. How long will the penny stay glowing?
6. Would other metals do the same when hung above the acetone?

**How to explain it:**

Holding the penny in the flame makes it so hot that it gives off a red glow. While the temperature of the penny is still high, it can speed up or facilitate the reaction of:



Copper functions as a **catalyst** for the above reaction, speeding it up without participating in the reaction itself. The reaction is **exothermic**, thus it produces heat, which keeps the penny glowing. The glowing will stop only when all the acetone has evaporated. No other metal is as efficient a catalyst as copper for this particular reaction.



## 1.5.17. THE RISING SUDS

**What you need:** 1. Two tall cylinders or narrow jars.

2. Liquid detergent, glycerine, hydrogen peroxide ( $H_2O_2$ ), manganese dioxide ( $MnO_2$ ).

3. Two long stirrers (long straws will do).

**How to do it:**

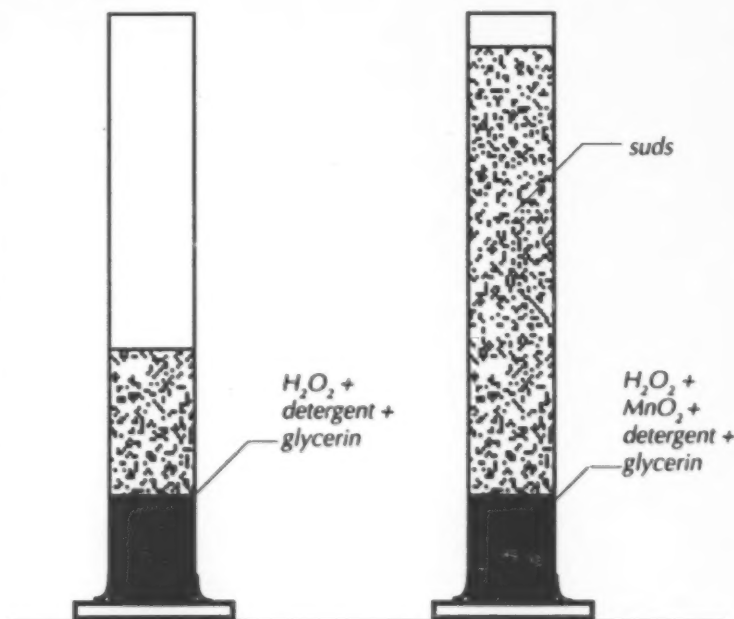
1. Place about 10 ml of hydrogen peroxide and 5 ml of detergent, and about 5 ml of glycerine in each cylinder/jar.
2. Add a pinch of  $MnO_2$  to one of the cylinders and stir the mixture in both cylinders with the long stirrers.
3. Observe the difference in height of the produced suds in the two tall cylinders.

**What to ask:**

1. In which of the two cylinders did the suds rise higher?
2. What causes the suds to go up higher in one of the cylinders?
3. What do we need to make soap bubbles?
4. What function does the peroxide have in this reaction?
5. What do the  $MnO_2$  and the glycerine do?
6. Would the suds rise just as high without the stirring?
7. What other substances might be used in place of  $MnO_2$ ?

**How to explain it:**

The detergent functions like the soap when blowing soap bubbles. By adding some glycerine to the detergent, the **surface tension** of the liquid is increased, and the bubbles will stay longer before collapsing. In order to get suds in a soap solution when blowing bubbles, we need to blow through a straw into the detergent mixture. In this case we do not need to blow. Where are we getting the gas to blow the bubbles from? The gas is supplied by the hydrogen peroxide, which decomposes into water and oxygen. The  $MnO_2$  acts as a **catalyst** for this oxygen producing reaction. It does not partake in the reactions but only facilitates it. This means that the properties of  $MnO_2$  before and after the reaction are unchanged. Dust and dirt particles or ashes could replace the  $MnO_2$ .





**What you need:** 1. A syrup bucket or any can with a tightly fitting friction lid.

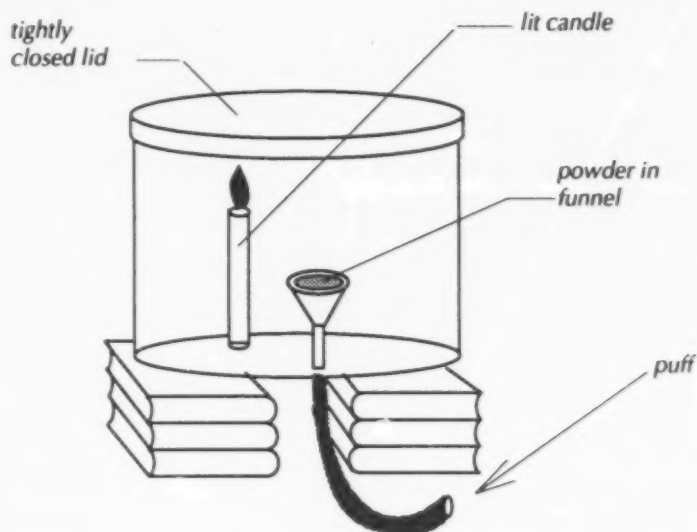
2. A small funnel & rubber tubing (1 m).

3. A 15 cm candle & small piece of tissue paper.

4. Lycopodium powder or corn starch.

**How to do it:**

1. Punch a hole in the bottom of the bucket (somewhat to the side) to fit the funnel stem (with the rubber tubing attached).
2. Set the bucket on two stacks of books to allow the funnel stem to protrude below the bottom (see Sketch).
3. Place a single thickness of tissue paper in the funnel mouth to support a teaspoon of lycopodium powder or corn starch.
4. Attach the candle on the opposite side of the funnel in the bucket and light it.
5. Close the bucket lid firmly and blow a sharp puff through the rubber tube (make sure you are demonstrating it under a sturdy ceiling and away from the lights!).



**What to ask:**

1. What made the bucket blow its top?
2. What is the purpose of the burning candle?
3. What reaction occurred inside the bucket?
4. Did all of the powder react? How do we know?
5. What other powders could we use in place of lycopodium?
6. Where do we find examples of this phenomenon in daily life?

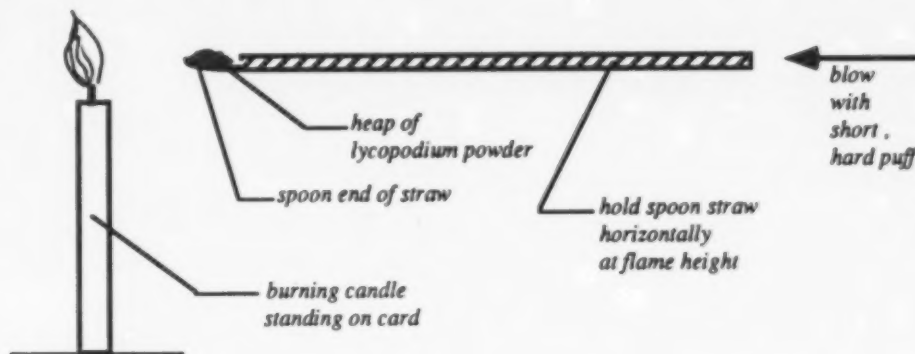
**How to explain it:**

At the moment that the powder was blown into the bucket, it was spread finely throughout the space and mixed with the existing air. As the powder consists of combustible hydrocarbons, it forms an **explosive mixture** with the oxygen in the air, and the lit candle is there to trigger the explosion. Most of the powder reacted with the oxygen to form  $\text{CO}_2$  and water vapor. These are gases, and their sudden production suddenly increased the pressure inside the bucket, resulting in blowing the bucket's top.

This phenomenon is encountered in coal mines full of coal dust, and when someone carelessly strikes a match an explosion is triggered.

## 1.5.19. THE STRAW FLAME THROWER

**What you need:** 1. A plastic spoon straw (or regular drinking straw)  
2. A candle & matches. 3. Lycopodium powder.

**How to do it:**

1. Light the candle and attach it to the table top or a 3x5 card (with a few drops of molten wax).
  2. Take the spoon straw or make one from a regular straw: cut about 1/2 inch into the straw with a pair of scissors, then cut perpendicular to the straw about half way and cut a spoon shape out of the cut piece (see above sketch).
  3. Dip the spoon in the lycopodium powder such that the spoon has a heap of powder on it.
  4. Hold the straw horizontally and direct it towards the flame of the candle: hold the spoon about 2 inches from the flame and put the other side of the straw in your mouth and blow a short hard puff into it.
  5. A variation to this would be: to place some lycopodium powder on your right palm and a lit match in your left hand; throw the powder into the flame!
- (CAUTION THE STUDENTS ABOUT THE DANGERS OF COMBUSTION!)**

**What to ask:**

1. What did you observe?
2. Where did all the powder go?
3. Will this also happen with regular flower or starch?
4. What can you conclude about the combustibility of lycopodium powder?  
About its kindling point?
5. Will the powder catch flame when the match flame is brought near a heap of the powder?
6. How can we lower or increase the kindling point of a certain material?

**How to explain it:**

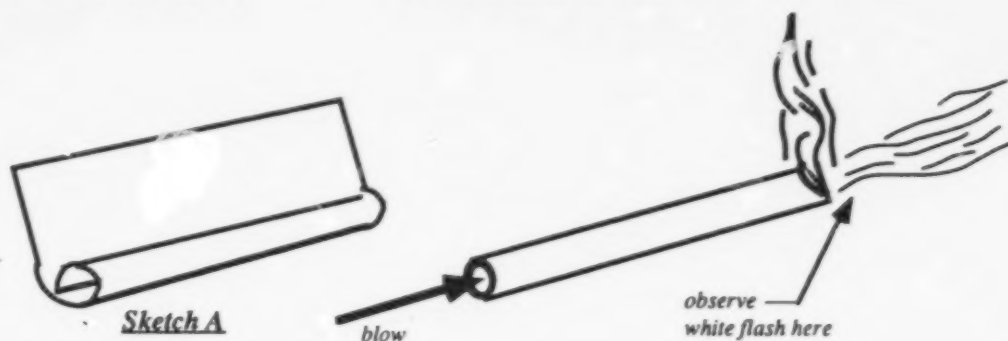
The physical condition of lycopodium powder is such that it is very finely divided. It consists of spores of club moss. Because it is so fine and very dry, its kindling point is very low; and since there is lots of air (or oxygen) around the particles, a sudden complete combustion takes place.

When we try this with regular flower or starch, we may succeed in getting combustion, but since the particles are usually larger and somewhat more moist, only a partial combustion is achieved.

Grinding matter very finely will decrease the **kindling point** - making it more combustible - and conglomerating it will increase this point - making it less combustible. Sparks in flower bins or coal mines may cause explosions and water sprayers will usually diminish this danger.

## 1.5.20. THE HUMAN FLAME THROWER

**What you need:** 1. A sheet of paper (towel or writing paper).  
2. A candle and match. 3. A container of water.

**How to do it:**

1. Light the candle and attach it to the table top or to a 3 x 5 card.
2. Roll up the sheet of paper rather tightly in a cylinder of about 3 cm diameter (see Sketch A).
3. Light one end of the paper roll with the burning candle and hold the roll horizontally with the burning end slightly upwards.
4. Without touching your lips to the other end of the paper roll, blow a short puff through the roll (the blowing can be repeated).
5. Observe a brighter flash of light and listen to the sound it makes!
6. Dump the burning paper in the container of water.

**What to ask:**

1. What makes the flame move outwards?
2. What causes the brighter flash of light?
3. What kind of sound did the flame make during the blowing?
4. Why must we hold the roll with the burning end slanted upwards?
5. What would happen if the burning end was held lower than the other end?
6. Why is it better to hold your lips a little away from the roll of paper when blowing through it?
7. What are the products of the burning process?
8. What are the elements that paper molecules are made up of?

**How to explain it:**

After burning one end of the paper roll, it is better to hold the burning end slightly higher than the other end, so that the smoke formed by the burning is flowing up and not through the roll to your mouth side. This demonstration works best if the roll was held perfectly horizontal. This way the smoke will be kept inside the roll and at the time that we blow, the smoke comes out the other end. This smoke mixed with the air **burst into flame** and gives a bright flash of light. At this moment we hear a ...pllaap...sound, indicating the sudden formation of gases.

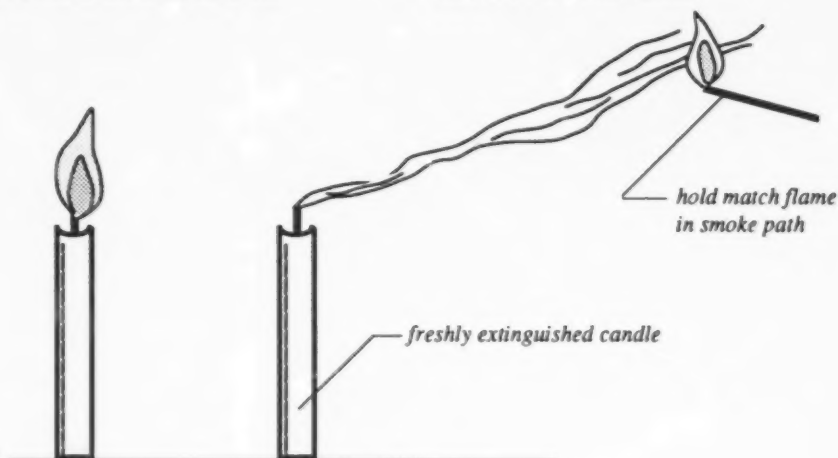
Paper is composed of plant fibers and these consist of cellulose molecules:  $C_{12}H_{22}O_{11}$  and when burned gives off  $CO_2$  (carbondioxide) **gas**, and **water vapor**, and leaves behind the black material, which is carbon (C).



## 1.5.21. THE MAGIC CANDLE

What you need: 1. A medium size candle.

2. A book of matches.



How to do it:

1. Light the candle and let it burn until the flame becomes a good size.
2. Strike another match. While holding the burning match in your hand, blow out the candle flame with a short puff.
3. Immediately after the flame is out, hold the flame of the burning match in the smoke trail coming from the candle wick (about 3-4 cm from the wick).
4. Observe the travelling flame! (If smoke trail is not thick enough, repeat points 1, 2, and 3 again. A draft-free room is needed to carry this out).

What to ask:

1. What makes the flame travel to the candle wick?
2. Why does this demo have to be carried out in a draft-free room?
3. What is actually burning of the candle?
4. Would wax without a wick sustain a flame?
5. What else beside a wick can we use to make wax sustain a flame?
6. What creates the smoke after a candle is blown out?

How to explain it:

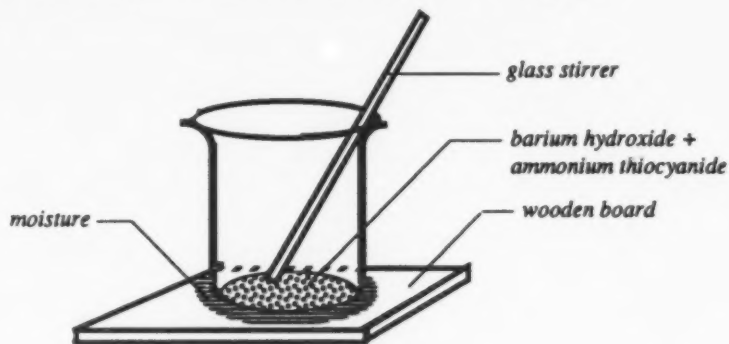
What is actually burning of a candle is the **vapor** which comes from the heated candle wax. When a candle is being lit, it is the wick that burns first. The heat of the flame melts the wax, the wick absorbs the molten wax and the hot wax vapors burn around the wick. When blowing out the candle flame, the hot wick keeps heating the molten wax. This is the reason why a smoke trail is formed. This smoke actually consists of very small **dispersed particles of wax in the air**, making it highly combustible. Holding a flame within this smoke trail sets it aflame and the flame "travels" to the wick.

The "Magic Candles" that can be bought in confectionery stores are candles which cannot be blown out. After blowing the flames out of these candles, they light themselves again. This is because the wax is treated with red phosphorus. The glowing wick will make the little particles of phosphorus spark up and make the candle burst back into flame.



## 1.5.22. THE STICKY BOARD

- What you need:**
1. A small beaker (250 ml), glass or plastic stirrer.
  2. A small thin wooden board (10 cm x 10 cm)
  3. Barium hydroxide -  $\text{Ba}(\text{OH})_2$  and ammonium thiocyanate -  $\text{NH}_4\text{SCN}$

**How to do it:**

1. Wet one side of the wooden board thoroughly with water.
2. Place the beaker on the wet side of the board.
3. Add one teaspoon of each of the chemicals to the beaker and stir while holding the beaker down tight to the board.
4. After the two chemicals are thoroughly mixed, lift the beaker slowly up (formation of frost on the outside of the beaker is an indication that it is ready to be lifted).

**What to ask:**

1. Why did the wooden board have to be wetted?
2. What kind of reaction occurred between the two chemicals?
3. Why did the wooden board stick to the beaker?
4. How else can we show that the reaction took away heat?
5. What other types of reactions do you know?

**How to explain it:**

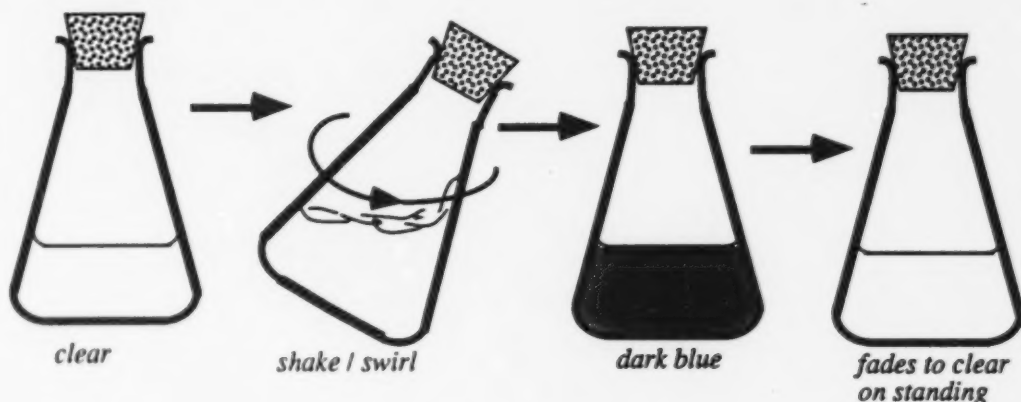
Most reactions are **exothermic**, which means that the reaction gives off heat (See Events 5.21 - 5.26), but this particular one is **endothermic**. This means that the reaction takes away heat, in other words the reaction requires calories in order for it to occur and if this heat is not supplied, it withdraws the heat from its environment. This cools down the environment and thus freezes the moisture that is between the beaker and the wooden board. This is the reason why the wooden board sticks to the beaker after the two chemicals are mixed in it. The reaction between the two chemicals is as follows:



We can see that the reaction gives off water also besides taking away energy, this is why the two dry chemicals become quite watery after mixing. It is therefore not necessary to add water to the reactants in the beginning of the mixing.

## 1.5.23. SHAKING THE BLUES

**What you need:** 1. An Erlenmeyer flask (250/400 ml) or pop bottle and stopper.  
2. Potassium hydroxide (5g), Glucose or dextrose (3g).  
3. Methylene blue.

**How to do it:**

1. Dissolve the above chemicals in the Erlenmeyer flask with 250 ml of water.
  2. Show to the students that it is a clear colorless liquid.
  3. Stopper the flask and shake the solution vigorously and show the change of color.
  4. Place the flask on the table and leave it standing.
  5. Draw students attention to the color of the solution.
- (The shaking may be repeated to show the color change for several hours).

**What to ask:**

1. What type of reaction is this? One that can be repeated seemingly almost endlessly?
2. When will the turning into the blue color stop? Or will it ever stop?
3. What makes the clear, colorless liquid turn blue?
4. What can we do to make the liquid turn blue again? (After it has stopped turning color?)

**How to explain it:**

Methylene blue is **reduced** to a colorless compound by an alkaline solution of a reducing sugar: in this case the glucose or dextrose. When we shake the flask, the colorless solution is **reoxylidized by the oxygen** above the liquid into the blue dye: methylene blue. When it is left standing, it is being reduced again, thus the gradual fading of the blue color.

Slowly, however, the oxygen in the flask above the liquid is seeping through the cork and is also reacting with the reducing sugar. This is why it eventually (after a few hours) stops changing into the blue color. To make the solution turn color again, the oxygen has to be replenished. This can be done by leaving the flask open to the air for a few moments.

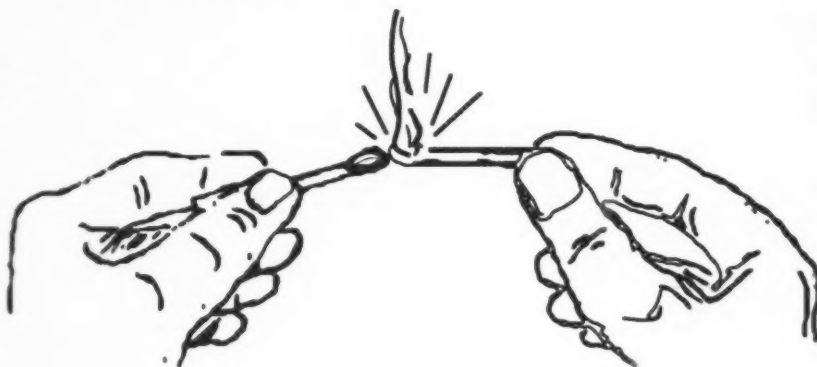
After a few days standing, the solution will turn yellow and to brown. A freshly prepared solution should be used for this demonstration.

## 1.5.24. THE STICKY MATCHES

**What you need:** 1. A box of wooden safety matches.

**How to do it:**

1. Take two match sticks out of the box and hold one in each of your hands.
2. Strike the one in your right hand against the box (if you are right handed) to light the match.
3. Immediately hold the lit match head against the match head in your left hand and wait till the left match gets lit.
4. As soon as the hissing sound of the ignition stops, blow out the flame. Make sure that you are holding the two matches with a steady hand against each other (see Sketch above).
5. Slowly let go of the match in your right hand (without moving/jarring the match - if you don't succeed the first time, try again!)



**What to ask:**

1. What made the two matches stick together?
2. What would happen if the first match was put against the second match not immediately after it was lit?
3. How are matches produced?
4. What are matches made of?
5. What is the match head made of?
6. What makes a match head burst into flame when rubbed against the box?
7. What chemical is on the striking surface of the box?

**How to explain it:**

The red tips of the matches burn and **fuse** together, making the matches stick. The burning of the red tips form chemicals that are porous and rough in texture. These porous and rough tips "grab" each other and thus making the matches stick together.

The match stick itself is made of softwood veneer. The wood splints are soaked into a bath of sodium silicate, ammonium phosphate or sodium phosphate and then dried. This **impregnation** prevents the **afterglow**. The wood splint is then dipped in a paraffin bath, which sustains burning. The match head consists of an **oxygen carrier** (potassium chlorate, chromate or lead oxide), sulfur and abrasives like powdered glass, and binding agents (dextrin or gums).

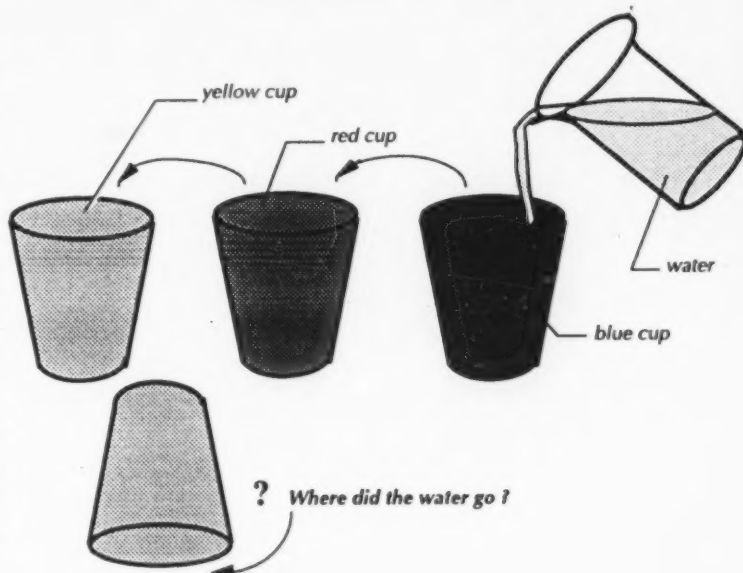
The side of the box contains red phosphorus and powdered glass. Safety matches can only be lit by striking against the side of the box. The **friction** produces heat, which releases the oxygen from the potassium chlorate and this reacts with the sulfur to produce the flame.

## 1.5.25. THE VANISHING WATER

**What you need:** 1. Three small opaque cups of different colors (red, blue & yellow).  
2. Polyacrylate (or the powder from the insides of Pampers). 3. Jug of water.

**How to do it:**

1. Put some polyacrylate in the yellow cup - just enough to cover the bottom. (do not show this to the students)
2. Place the three cups on the table and pour some water (1/4 cup) in the red cup. Move the three cups around and ask: "Where is the water now?"
3. Now pour the water from the red cup into the blue cup, move the cups around and ask: "where is the water now?" Anticipated answer: "In the blue cup".
4. Now pour the water from the blue cup into the yellow cup, move the cups around and ask: "Where is the water now?" Anticipated answer: "In the yellow cup".
5. Turn all three cups upside down: **the water vanished !**

**What to ask:**

1. Where did the water go to?
2. What was the moving around of the three cups for?
3. Could we have done the same with larger cups?
4. Why do we need opaque cups? Could transparent cups be used?
5. What state of matter did the water actually change into?
6. How could we change the demonstration, if we only had transparent glasses?

**How to explain it:**

Polyacrylate is a high polymer that has the characteristic and capacity of **absorbing over 800 times its weight of water**. This is why it is being used inside the cotton pads of baby pampers. When using larger cups, more of the white powder is needed to absorb more of the water.

The moving around of the three cups was necessary for the little time that is needed for the water to get absorbed by the polyacrylate. The opaque cups, of course, concealed the presence of the powder in the yellow cup and also the changing of the water into the solid gel.

If we used transparent cups, the demonstration could be used to deal with states of matter where suddenly a liquid is being transformed into a solid. It takes only a few seconds before the cup with the water can be turned upside down!



## APPENDIX

**Table 1. HUMIDITY CHART**

|                                             | Difference between Dry- and Wet-bulb Thermometers |     |     |     |     |     |     |     |     |     |     |     |     |     |
|---------------------------------------------|---------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Degrees (C)                                 | 0.5                                               | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 |
| Reading of Dry-bulb Thermometer (Degrees C) | Percent Humidity                                  |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 17.5                                        | 95                                                | 89  | 84  | 79  | 74  | 69  | 64  | 60  | 55  | 51  | 46  | 42  | 38  | 33  |
| 18                                          | 95                                                | 89  | 84  | 79  | 74  | 70  | 65  | 60  | 56  | 51  | 47  | 43  | 38  | 34  |
| 18.5                                        | 95                                                | 90  | 85  | 80  | 75  | 70  | 65  | 61  | 56  | 52  | 48  | 44  | 39  | 35  |
| 19                                          | 95                                                | 90  | 85  | 80  | 75  | 71  | 66  | 61  | 57  | 53  | 49  | 45  | 40  | 36  |
| 19.5                                        | 95                                                | 90  | 85  | 80  | 76  | 71  | 66  | 62  | 58  | 53  | 49  | 45  | 41  | 37  |
| 20                                          | 95                                                | 90  | 85  | 81  | 76  | 71  | 67  | 63  | 58  | 54  | 50  | 46  | 42  | 38  |
| 20.5                                        | 95                                                | 90  | 86  | 81  | 76  | 72  | 67  | 63  | 59  | 55  | 51  | 47  | 43  | 39  |
| 21                                          | 95                                                | 90  | 86  | 81  | 77  | 72  | 68  | 64  | 60  | 55  | 52  | 48  | 44  | 40  |
| 21.5                                        | 95                                                | 91  | 86  | 81  | 77  | 72  | 68  | 64  | 60  | 56  | 52  | 48  | 45  | 41  |
| 22                                          | 95                                                | 91  | 86  | 82  | 77  | 73  | 69  | 65  | 61  | 57  | 53  | 49  | 45  | 42  |
| 22.5                                        | 95                                                | 91  | 86  | 82  | 78  | 73  | 69  | 65  | 61  | 57  | 53  | 50  | 46  | 42  |
| 23                                          | 95                                                | 91  | 86  | 82  | 78  | 74  | 70  | 66  | 62  | 58  | 54  | 50  | 47  | 43  |
| 23.5                                        | 95                                                | 91  | 87  | 82  | 78  | 74  | 70  | 66  | 62  | 58  | 55  | 51  | 47  | 44  |

**Table 2. DENSITIES OF SUBSTANCES**

| SUBSTANCE       | DENSITY (g/cc) |
|-----------------|----------------|
| Mercury         | 13.6           |
| Lead            | 11.3           |
| Steel           | 7.6 - 7.8      |
| Aluminum        | 2.70           |
| Glass           | 2.4 - 2.8      |
| Glycerine       | 1.27           |
| The human body  | 1.07 (Average) |
| Water           | 1              |
| Ice             | 0.917          |
| Alcohol (ethyl) | 0.794          |
| Cork            | 0.24           |
| Room Air        | 0.0012         |
| Hydrogen        | 0.000089       |



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## NOTES



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*If you had to invite a speaker to do a presentation to teachers or students of science, or to the general public on the topic of science and how to teach it, Dr. Tik L. Liem would most likely rank at the top of your list.*

*Of Chinese-Indonesian origin and Dutch as his native language, with a Chemical Engineering background and a Ph.D. from Cornell University, and more than 25 years of experience teaching teachers how to teach science, he puts a lot of vigor and enthusiasm in his presentations and makes science truly come alive!*

*Dr. Liem is also the author of "INVITATIONS TO SCIENCE INQUIRY", a 500 page book for teachers containing over 400*

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